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Open-ended Working Group of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
Twelfth meeting
Geneva (online), 22–25 June 2020*
Item 3 (b) (i) c. of the provisional agenda**

Matters related to the work programme of the Open-ended Working Group for the biennium 2020–2021: scientific and technical matters: technical guidelines: technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal

Draft updated technical guidelines on the identification and environmentally sound management of plastic wastes and for their disposal

Note by the Secretariat

1. As is mentioned in the note by the Secretariat on technical guidelines (UNEP/CHW/OEWG.12/4), the small intersessional working group on plastics wastes updated the technical guidelines on the identification and environmentally sound management of plastic wastes and for their disposal adopted by decision VI/21,[1] as set out in the annex to the present note.

2. The changes made by the small intersessional working group to the technical guidelines adopted by decision VI/21 have not been tracked as the updated technical guidelines have been restructured in way that such revisions could not be easily identified. A note by the co-leads explains some points about the process followed in the intersessional period is set out in the annex to the present note.

3. The present note, including its annex, has not been formally edited.

* Owing to the electronic correspondence procedure to be applied during the twelfth meeting of the Open-ended Working Group, the meeting may run beyond 25 June (but no later than 5 July 2020).

** UNEP/CHW/OEWG.12/1.

[1] UNEP/CHW.6/21, annex.

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Annex

Draft updated technical guidelines on the identification and environmentally sound management of plastic wastes and for their disposal

(Draft of 21 May 2020)

Note from the Co-leads:

At the end of 2019, pursuant to part V of decision BC-14/13, and based on input from the small intersessional working group (SIWG) on plastic wastes, a first updated draft of these guidelines was developed and circulated among the group members and observers. Following this first draft, several Parties and observers have provided comments, which were the basis for the development of the second updated draft, which is presented in this document.

However, giving the complexity of the topics covered by these guidelines, the co-lead countries China, Japan and the United Kingdom of Great Britain and Northern Ireland would like to highlight that not every comment provided so far has been taken into account and that some of them will require further discussion of the SIWG.

Where possible, it is indicated that further text or details should be added at a later stage.

Contents

Abbreviations

(to be completed)

ABS	Acrylonitrile butadiene styrene
ABS FR	Flame Retardant ABS
ADF	Advanced disposal fees
ASTM	American society for testing and materials
BAT	Best available techniques
BEP	Best environmental practices
BET	Best Available Techniques
BFRs	Brominated flame retardants
CEN	European committee for standardization
CENELEC	European committee for electrotechnical standardization
decaBDE	decabromodiphenyl ether
DEHP	di (2- ethylhexyl) phthalate
DRS	Deposit-and-return system
EPA	Environmental protection agency
EPR	Extended producer responsibility
ePRNS	Electronic packaging waste recovery notes
EPS	Expandable polystyrene
ESM	Environmentally sound management
EU	European Union
FEP	Perfluoroethylene/propylene
GEMS	Global environment monitoring system
GHG	Greenhouse gas
GPML	Global Partnership on Marine Litter
HBCD	Hexabromocyclododecane
HDPE	High-density polyethylene
HIPS	High Impact Polystyrene
HIPS FR	High Impact Polystyrene Flame Retardant
IATA	International air transport association
IMO	International maritime organization
ISO	International organization for standardization
ISWA	International solid waste association
LCA	Life Cycle Analysis
LDPE	Low-density polyethylene
MCCPs	Medium chain chlorinated paraffins
MFA	Tetrafluoroethylene/perfluoromethyl vinyl ether
MSW	Municipal solid waste
NA	Neutralisation Agent
NIR	Near-infrared
OECD	Organisation for economic co-operation and development
PA	Polyamide
PBAT	Polybutyrate adipate terephthalate
PBDEs	Polybrominated diphenylethers
PC	Polycarbonate
PCL	Polycaprolactone
PDF	Packaging derived fuel
PE	Polyethylene
PET	Polyethylene terephthalate
PF	Polymer fuel
PFA	PerFluoroAlkanes
POP	Persistent organic pollutants
PP	Polypropylene
PS	Polystyrene
PTT	Polytrimethylene Terephthalate
PUR	Polyurethane
PVA	Polyvinyl Alcohol

PVC	Polyvinyl chloride
PVDF	Polyvinylidenefluoride
PVF	Polyvinylfluoride
QAQC	Quality assurance and quality control
RDF	Refuse Derivel Fuel
RIC	Resin identification coding
SAICM	Strategic Approach to International Chemical Management
SOP	Standard operational procedure
TBBP-A	Tetrabromobisphenol
TPE	Thermoplastic elastomer
UNEA	United Nations Environmental Assembly
UNECE	United Nations Economic Commission for Europe
VIS	Visual Spectrometry
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization
XPS	Extruded Polystyrene
XRF	X-ray Flouresence
XRT	X-ray Transmissio*n*

Units of measurement

cm	centimetre
µg/kg	microgram(s) per kilogram. Corresponds to parts per billion (ppb) by mass.
kg	kilogram
kW	kilowatt
kWh	kilowatt-hour
mg	milligram
mg/kg	milligram(s) per kilogram.
MJ	megajoule
ms	millisecond
ng	nanogram
Mg	megagram (1,000 kg or 1 tonne)
Nm^3	normal cubic metre; refers to dry gas, 101.3 kPa and 273.15 K
tonne	1000 kg

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I. Introduction

A. Scope

1. These technical guidelines provide guidance on the environmentally sound management (ESM) of plastic wastes, pursuant to decision BC-14/13 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.[1]

2. Normally, Basel Convention technical guidelines apply to those wastes which fall under Annex I of the Convention and possess any of the characteristics of Annex III, as well as to wastes listed under Annex II of the Convention which require special consideration.

3. The Amendments to Annex II, VIII and IX to the Basel Convention, adopted by the Conference of the Parties at its fourteenth meeting, bring within the scope of the Convention most of plastic waste; and any plastic waste transboundary movement (TBM) which are not destined to be recycled in an environmentally sound manner and/or not almost free from contamination and other types of wastes, and/or made up of multiple polymer types with the exception of mixtures of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided these permitted mixtures are destined for separate recycling.

4. 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 include plastic wastes extracted and/or separated from other waste streams that have plastic components or consist partially of plastic (e.g. Waste Electrical and Electronic Equipment (WEEE), waste vehicles, cables and lead-acid batteries, synthetic textiles for which there are separate related entries in Annexes VIII and IX).

5. These technical guidelines do not cover guidance on plastic waste containing or contaminated with POPs as such guidance is covered by the general technical guidelines for the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (POPs)[2] and the specific technical guidelines on HBCD,[3] POP-BDEs[4] and SCCPs.[5]

6. These technical guidelines could be used refering to the following specific technical guidelines;

(a) Draft guidance document on the environmentally sound management of household wastes (under preparation, Basel Secretariat);

(b) Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with short-chain chlorinated paraffins(UNEP/CHW.14/7/Add.2/Rev.1);

(c) Guidance on the environmentally sound management of plastic waste containing or contaminated with POPs is provided in the general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs) (UNEP/CHW.14/7/Add.1/Rev.1);[2]

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[1] UNEP (2002). Technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal. UNEP/CHW.6/21.

[2] UNEP (2019). General technical guidelines for the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (POPs) (UNEP/CHW.14/7/Add.1/Rev.1.

[3] UNEP (2017). Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane.- Addendum (UNEP/CHW.13/6/Add.2/Rev.1).

[4] UNEP (2015). 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 (POP-PBDEs) (UNEP/CHW.12/5/Add.6/Rev.1).

[5] UNEP (2018). Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with short-chain chlorinated paraffins (UNEP/CHW.14/7/Add.2/Rev.1).

(d) 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/CHW.13/INF/11/Rev.1);[6]

(e) Revised set of draft practical manuals for the promotion of the environmentally sound management of wastes (UNEP/CHW.13/4/Add.1);[7]

(f) Draft updated technical guidelines on incineration on land (D10);[8]

(g) Draft updated technical guidelines on use as a fuel (other than in direct incineration) or other means to generate energy (R1);[9]

(h) Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP/CHW.10/6/Add/3/Rev.1);[10]

(i) Draft updated technical guidelines on specially engineered landfill (D5) (UNEP/CHW/OEWG.11/INF/19);[11]

(j) Guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP/CHW.14/INF/8);[12]

(k) Practical manuals on extended producer responsibility and financing systems for environmentally sound management (UNEP/CHW.14/5/Add.1);[13]

(l) Revised draft practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements (UNEP/CHW.14/INF/6);[14]

(m) Guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous and other wastes (UNEP/CHW.14/INF/7);[15]

(n) PACE (Partnership for Action on Computing Equipment) guidelines and manuals on management of computing equipment;

(o) Interim revised technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention (UNEP/CHW.14/7/Add.6/Rev.1);[16]

(p) Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane.[17]

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[6] UNEP (2019). 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/CHW.14/INF/7.

[7] UNEP (2017). Revised set of draft practical manuals for the promotion of the environmentally sound management of wastes (UNEP/CHW.13/4/Add.1).

[8] Pending.

[9] Pending.

[10] UNEP (2011). Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns. Addendum (UNEP/CHW.10/6/Add/3/Rev.1).

[11] UNEP (2018) Draft updated technical guidelines on Specially Engineered Landfill (D5) (UNEP/CHW/OEWG.11/INF/19).

[12] UNEP (2019) Revised draft guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP/CHW.14/INF/8).

[13] UNEP (2019). Revised draft practical manuals on extended producer responsibility and financing systems for environmentally sound management (UNEP/CHW.14/5/Add.1).

[14] UNEP (2019). Revised draft practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements (UNEP/CHW.14/INF/6).

[15] UNEP (2019). Guidance to assist Parties in developing efficient strategies for achieving recycling and recovery of hazardous and other wastes (UNEP/CHW.14/INF/7).

[16] UNEP (2019). Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention. Addendum (UNEP/CHW.14/7/Add.6/Rev.1).

[17] UNEP, (2015). Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane.

7. The current technical guidelines address and provide guidance on:

(a) Various common plastic types and their composition;

(b) Legislative and regulatory framework;

(c) Plastic wastes prevention and minimization;

(d) Identification of plastic wastes and inventories;

(e) Sampling and analysis;

(f) Safe handling, separation, collection, packaging, compaction, storage, transport and shipping of plastic wastes;

(g) Environmentally sound recycling, energy recovery and final disposal of plastic wastes;

(h) Considerations of degradable plastics.

B. About plastics and plastic wastes

8. It was only in the 1950s that plastics began to come into wide use and within a few years production rose at a high rate.[18] The amount of plastic produced has grown constantly since then, reaching, from 2 million tonnes in 1950, to 454[19] million tonnes in 2018.[20] By 2015, it was estimated that 79% of all plastic wastes generated worldwide had been landfill or dumped, a further 12% incinerated and only 9% recycled.[21] In addition, it has been estimated that in 2010, 4.8 to 12.7 million tonnes of plastic waste ends up in the oceans annually.[22]

9. Currently, consumers are exposed to an extensive variety of plastic products. Plastics are lightweight, with varying degrees of strength, they can be both thermal and electrical insulators, they can be molded in various ways, and they offer a large range of characteristics and colors, which are achieved through chemical additives.[23] However, plastics can also pose challenges related to its proven impacts on human health and the environment. The first scientific reports about the fate of plastic in the environment and in wildlife were published in 1969,[24] but only recently, has attention focused on marine litter issues – a consequence of extensive mismanagement of plastic waste.

10. In 2019, the global plastic market was dominated by thermoplastic[25] types of polypropylene (PP) (19%), low -and linear low-density polyethylene (LDPE and LLDPE) (15%), polyvinyl chloride (PVC) (13%), and high-density polyethylene, (HDPE) (13%). Other plastic types with high demand were polystyrene (PS), and expandable PS (6%), and polyethylene terephthalate (PET) (6%).[26]

11. Plastics are most commonly used for packaging and food containers, but they have also found applications in building and construction, transportation, electronics, agriculture, healthcare, sport and energy generation. Some plastics are used for many years such as

[18] Geyer,R., Jambeck, R.J., Lavender, K.L, (2017), Production, use, and fate of all plastics ever made. Available at: https://www.researchgate.net/publication/318567844_Production_use_and_fate_of_all_plastics_ever_made

[19] 382 million tonnes plastic resins and fibers, and 25 million tonnes of additives.

[20] Geyer, 2020, New unpublished data.

[21] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science advances*, *3*(7), e1700782. https://www.researchgate.net/publication/318567844_Production_use_and_fate_of_all_plastics_ever_made downloaded on 08/01/20.

[22] Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, *347*(6223), 768-771. https://www.iswa.org/fileadmin/user_upload/Calendar_2011_03_AMERICANA/Science-2015-Jambeck-768-71__2_.pdf downloaded on 08/01/20.

[23] ACC, Life cycle of a plastic product. Available at: https://plastics.americanchemistry.com/Lifecycle-of-a-Plastic-Product/.

[24] Kenyon, K.W., and Kridler, E. 1969. Laysan Albatrosses swallow indigestible matter. Auk, 86: 339-343.

[25] Plastics that can be melted and recast almost indefinitely.

[26] PEMRG 2019 ....PENDING FULL REFERENCE FROM Plastics Europe.

building materials; however, the majority are only used for a short time between one day or less (e.g., certain plastic cups, plates, takeaway containers, plastic bags etc.) or a few years (e.g. food and drink containers, cosmetics, agricultural film etc.).[27]

12. The plastics value chain includes the full range of activities, which are required to bring a plastic product through the different phases of extracting raw materials, production, distribution to consumers, and final disposal after use. The lifecycle of plastics lifecycle includes three main phases (Figure 1):

(a) Production phase;

(b) Use phase;

(c) End of life phase.

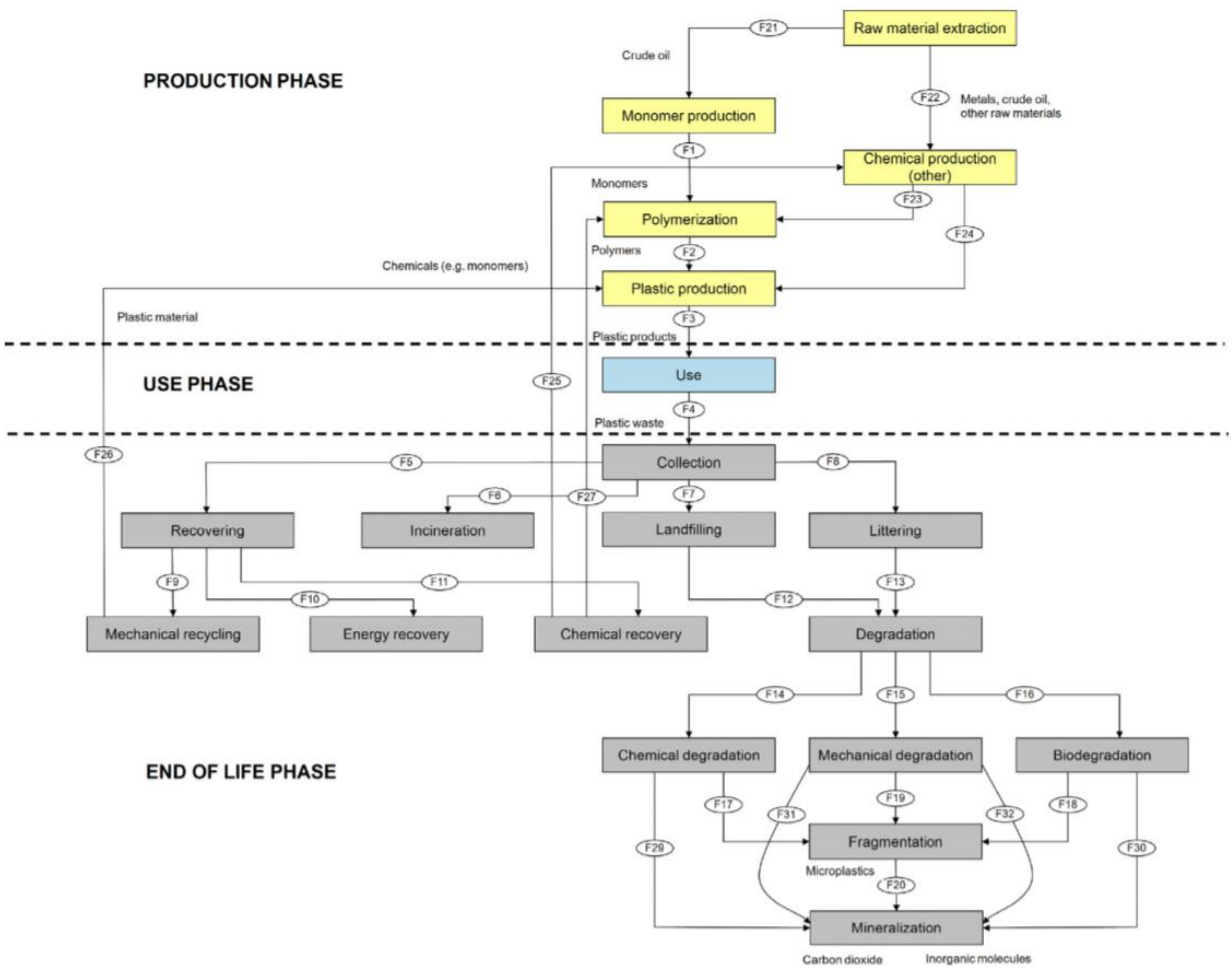


Figure 1: The life cycle of plastic products (excluding energy input and emissions). Adopted from[28]

[27] Resource Futures and Nextek, (2018), Eliminating avoidable plastic waste by 2042: a use-based approach to decision and policy making. Retrieved from: https://www.circularonline.co.uk/wp-content/uploads/2019/06/Eliminating-avoidable-plastic-waste-by-2042-a-use-based-approach-to-decision-and-policy-making.pdf.

[28] 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 at: https://www.sciencedirect.com/science/article/pii/S030438941730763X, downloaded on 08/01/20.

13. The value chain of plastic remains archetypically linear with less than 20%[29] of plastics re-entering the value chain and huge amounts of plastics ending up in terrestrial and marine environments each year.

14. The most intractable problem so far relating to plastics and the environment has been their sustainable end of life management. Median waste collection coverage is still around 50% in low-income countries and figures are much lower in some countries. It also drops sharply in the more rural areas of many countries. In addition, it is estimated that at least 2 billion people worldwide still lack access to solid waste collection.[30]

15. In high and upper-middle income countries the 100% and 95% controlled disposal rates respectively are in stark contrast with rates that are often well below 50% in low-income countries, and 0% controlled disposal is still relatively common in rural areas in many countries.[31] Furthermore, the OECD estimated in 2018 that nearly 80% of all plastics produced were left to accumulate in landfills or the natural environment.[32]

16. Landfilling is increasingly seen to pose problems, such as the leaching of plastics additives and whole plastics particles from landfill sites into the wider environment. Furthermore, poorly managed landfills and uncontrolled open burning might incidentally or, even deliberately occur and create impacts for air quality.

17. The controlled incineration of plastic waste is also raising concerns regarding climate impacts due to greenhouse gas (GHG) emissions, toxic pollution and POPs creation.

18. The escape of plastic into the environment can occur from a variety of land-based and ocean-based sources in the form of macroplastics and microplastics (small plastic particulates below 5 mm in size).The main land based sources of plastic releases are the uncontrolled dumping of waste and littering by members of the public from day-to-day and recreational activities.[33]

19. The exact lifetime of discarded plastics depends on the chemical nature of the material the characteristics of the environment in which it is discarded and how susceptible is to degradation.[34]

C. Common types of plastics and their composition

1. What is plastic?

20. The word plastic derives from the Greek word ‘plastikos’ meaning "capable of being shaped or moulded" and, in turn, from the word ‘plastos’ meaning "moulded".[35]

21. A plastic material is an organic substance, either a polymer or combination of polymers of high molecular mass modified or compounded with additives. According to ISO 472:2013 (Plastics Vocabulary) 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.[36]

[29] Geyer, R., Jambeck, R.J., and Law K.L., 2017, Production, Use, and Fate of all Plastics ever Made, Science Advances 19 Jul 2017: Vol. 3, no. 7, e1700782, Retrieved from: https://advances.sciencemag.org/content/3/7/e1700782.

[30] Global Waste Management Outlook 2015.

[31] Pending reference.

[32] https://www.oecd.org/environment/waste/policy-highlights-improving-plastics-management.pdf.

[33] Velis, C., Lerpiniere, D., Tsakona, M., 2017, How to prevent marine plastic litter - now! An ISWA facilitated partnership to prevent marine litter, with a global call to action for investing in sustainable waste and resources management worldwide. Report prepared on behalf of the International Solid Waste Association (ISWA). An output of ISWA Marine Litter Task Force. ISWA September 2017. Vienna, pp.75, Retrieved from: http://marinelitter.iswa.org/marine-task-forcereport- 2017/.

[34] Andrady, L.A., and Mike A. Neal,M.A, (2009), Applications and societal benefits of plastics. Philos Trans R Soc Lond B Biol Sci. 2009 Jul 27; 364(1526): 1977–1984. Retreived from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873019/.

[35] Plastikos, Henry George Liddell, Robert Scott, A Greek-English Lexicon, at Perseus. Perseus.tufts.edu; Plastic, Online Etymology Dictionary etymonline.com.

[36] https://www.iso.org/obp/ui/#iso:std:iso:472:ed-4:v1:en.

22. A polymer is a chain of several thousand repeating molecular units or several different types of monomerswhich are either natural or synthetic organic compounds.[37]

23. The main distinction between polymers and plastics is that polymers with the addition of additives, such as fillers, plasticizers, stabilizers, lubricants, pigments, etc, are becoming plastic materials.

2. Category and degradability in the environment of common polymers

24. Currently, there are more than 30 types of primary plastics, which combined with a range of different additives, can give thousands of plastic materials.[38] 97-99%[39] of these plastics are derived from fossil fuel feedstock while the remaining 1-3% comes from bio(plant) based plastics.[40]

25. There are a wide range of polymers used in common plastics with different properties, which make them appropriate for different applications. Common polymer types are listed in Table 1.

Table 1: Plastics, common uses and properties

<table>
<tr><th colspan="2">Symbol</th><th>Polymer</th><th>Common uses</th><th>Properties[41]</th></tr>
<tr><td colspan="2">PET</td><td>Polyethylene terephthalate</td><td>plastic bottles (water, soft drinks etc.) food packaging film, strapping, carpets, vehicle tyre cords, fibres</td><td>Clear, strong and lightweight</td></tr>
<tr><td colspan="2">PE</td><td>Polyethylene</td><td>packaging (plastic bags, plastic films, geomembranes, containers including bottles, etc.).</td><td>High ductility and impact strength as well as low friction</td></tr>
<tr><td rowspan="2">Most common</td><td>HDPE</td><td>High-density polyethylene</td><td>milk containers, shampoo bottles, cleaning agents, etc.</td><td>Stiff and hardwearing; hard to breakdown in sunlight</td></tr>
<tr><td>LDPE</td><td>Low-density polyethylene</td><td>Plastic bags, plastic food wrapping (e.g. fruits, vegetables)</td><td>Lightweight, low-cost, versatile; fails under mechanical and thermal stress</td></tr>
<tr><td colspan="2">PVC</td><td>Polyvinyl chloride</td><td>plastic piping, vinyl flooring, cabling insulation, roof sheeting</td><td>Can be rigid or soft via plasticizers; used in construction, healthcare, electronics</td></tr>
<tr><td colspan="2">PP</td><td>Polypropylene</td><td>Bottle lids, food tubs, furniture, automobile parts etc.</td><td>Tough and resistant; effective barrier against water and chemicals</td></tr>
<tr><td colspan="2">PS</td><td>Polystyrene</td><td>Plastic cutlery, food take away containers</td><td>Lightweight; structurally weak; easily dispersed</td></tr>
<tr><td colspan="2">ABS</td><td>Acrylonitrile butadiene styrene</td><td>Computers, televisions, kitchen appliances, and toys such as Lego, Keyboard keycaps, musical instruments, automobile components [42],[43] [44] 3d printing</td><td>Lightweight; resistance and toughness, chemical resistance performance</td></tr>
</table>

[37] Villanueva, A., & Eder, P. (2014). End-of-waste criteria for waste plastic for conversion. *Institute for Prospective Technological Studies*. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC91637/2014-jrc91637%20.pdf.

[38] Silvestre,Cl., Cimmino,S., 2013, Ecosustainable Polymer Nanomaterials for Food Packaging: Innovative Solutions, Characterization Needs, Safety and Environmental Issues.

[39] Center for International Environmental Law, 2017, Fueling Plastics, Fossils, Plastics, & Petrochemical Feedstocks. Retrieved from: https://www.unpri.org/download?ac=9629.

[40] European Bioplastics, 2016, Bioplastic market data 2016. Retrieved from: https://docs.european-bioplastics.org/publications/EUBP_Bioplastics_market_data_report_2016.pdf.

[41] Ritchie, H., 2 September 2018, FAQs on Plastics, Available: https://ourworldindata.org/faq-on-plastics.

[42] ABS – acrylonitrile butadiene styrene On Designsite.dk, lists applications. Available at: https://www.ceresana.com/en/market-studies/plastics/engineering-plastics/.

[43] Market Study Engineering Plastics, Retrieved from: http://designinsite.dk/htmsider/m0007.htm.

[44] Keycap Construction: ABS. Retrieved from: https://deskthority.net/wiki/Keycap_material.

Symbol	Polymer	Common uses	Properties[41]
PC	Polycarbonates	Electronic applications, Products in construction industry (e.g. for domelights, flat or curved glazing, and sound walls) Compact Discs, DVDs, and Blu-ray Discs Automotive, aircraft, railway, and security components	Strong, tough materials, and some grades are optically transparent
OTHER	Other plastics (e.g. acrylic, polyactic fibres etc.)	Fiberglass, water cooler bottles	Diverse in nature with various properties

26. Polymers can be classified based on source, on structures, on mode of polymerization and on molecular forces (Figure 2).

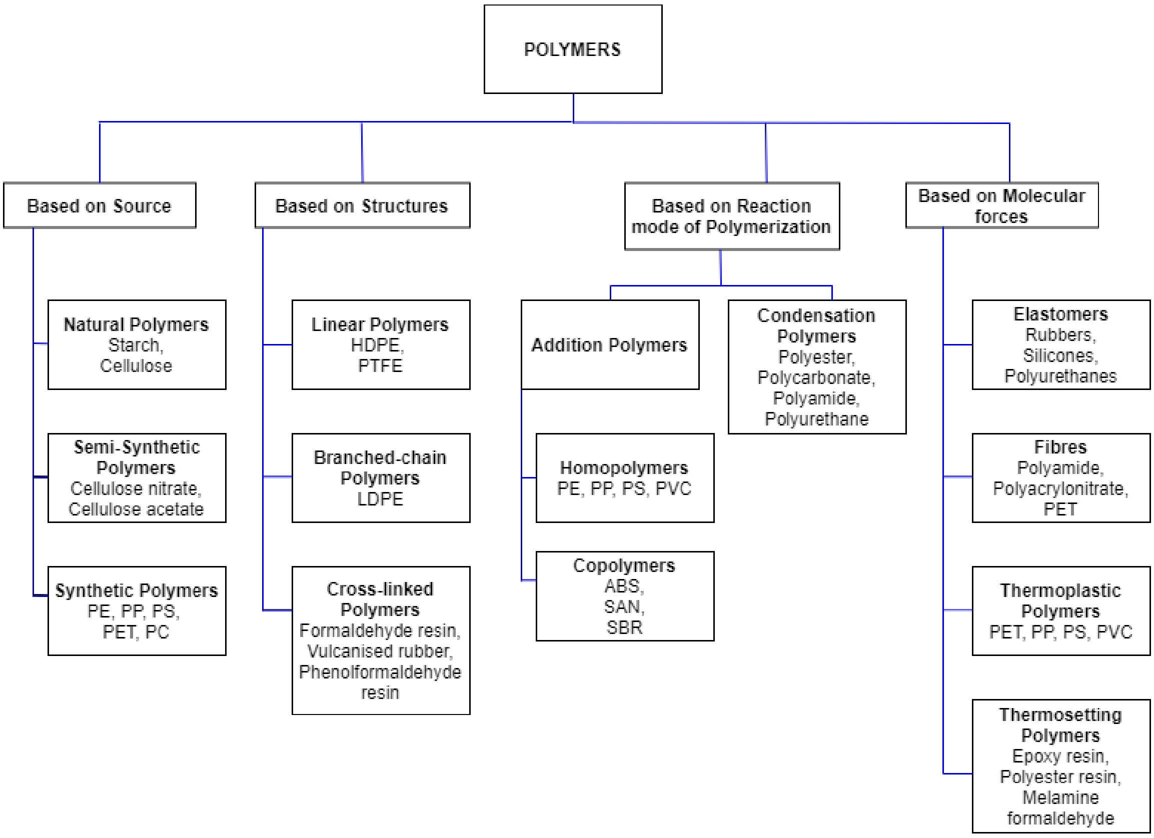


Figure 2: Classification of Polymers[45]

27. The most common way of classifying polymers is to separate them into four groups - thermoplastics, thermosets, elastomers and fibers.

(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), polystyrene (PS) and polyvinyl chloride (PVC). Most common consumer plastics are thermoplastics;

(b) Thermosets are plastics that are set into a mould once and cannot be re-softened or moulded again. Examples of thermoset include phenolic resins, amino resins, polyester resins, and polyurethanes. Thermosets are ideal for high-heat applications such as electronics and appliances;

[45] https://textilechemrose.blogspot.com/2018/09/classification-of-polymer.html.

(c) Elastomers are polymers with the property of "elasticity," generally having notably low elastic properties and high yield strain compared with other materials.[46] Elastomers may be thermosets or thermoplastics (thermoplastic elastomer or TPE).[47] Neoprene which is used in applications such as laptop sleeves, orthopedic braces (wrist, knee, etc.) and electrical insulation is an example of an elastomer;

(d) Synthetic fibers are artificial fibers made by chemical synthesis, as opposed to natural fibers that are directly derived from living organisms. They have strong inter-molecular forces between the chains giving them less elasticity and high tensile strength. In general, synthetic fibers are created by extruding fiber-forming materials through spinnerets, forming a fiber. Common synthetic fibers are nylon-66 (used in carpets and textiles), modacrylic, olefin, acrylic and polyester fibres;

(e) Bio-based plastics are seen as alternatives to conventional plastic especially in the context of the end-of-life environmental impacts. However, depending of the material used, bio-based plastics can be biodegradable or non-biodegradable which will dictate the waste management options for these materials. Non-biodegradable plastics, as the term suggest, do not degrade and are less recycled than conventional plastic. More information is provided in Section V.

28. Mixed plastics can consist of several different types of polymers, as well as of composite materials containing plastics bound to other materials such as metals (for instance in wrappers and sachets) or cardboard (for instance in beverage cartons).

29. Certain mixtures of polymers can give rise to reliable materials, while in others minute concentrations of unwanted polymers can have detrimental effects. Such miscibility and compatibility increase between polymers of the same family (e.g. PE & PP belong to the polyolefin family and PS and ABS belong to the styrenics family). Furthermore, compatibility can be enhanced through certain compatibilizer additive technology. Tolerances will be highly dependent on the specific polymers being used and design for recycling can play an important role in terms of compatibility of polymers and the requirements of the end application.[48]

30. Degradability of polymers in the environment: The susceptibility of a polymer to degrade depends on its structure, additives included and the environment. Degradation of plastics can proceed by abiotic mechanisms (photodegradation, thermooxidative degradation, chemical degradation, hydrolysis and mechanical degradation) or biotic mechanisms (biodegradation by microorganisms).[49]

31. Generally abiotic degradation of plastics precedes biodegradation, and is initiated thermally, hydrolytically, or by UV-light in the environment. Smaller polymer fragments formed by abiotic degradation can pass through cellular membranes and be biodegraded by enzymes. During biodegradation the plastic is converted to its monomers, followed by mineralization of the monomers (Figure 3)51. A number of microorganisms that can potentially biodegrade plastics are provided in Appendix 1.

32. When considering the degradation pathways of plastics, they can be divided into two groups: plastics with carbon-carbon backbone (e.g., PE, PS, PP and PVC) and plastics with heteroatoms (e.g., PET and PU) in the main chain. Plastic materials made of polymers consisting of carbon and hetero atoms in the main chain have increased thermal stability compared to polymers with a solely carbon backbone.[50]

[46] McKeen LW. (2008) The effect of temperature and other factors on plastics, plastics design library. William Andrew Publishing.

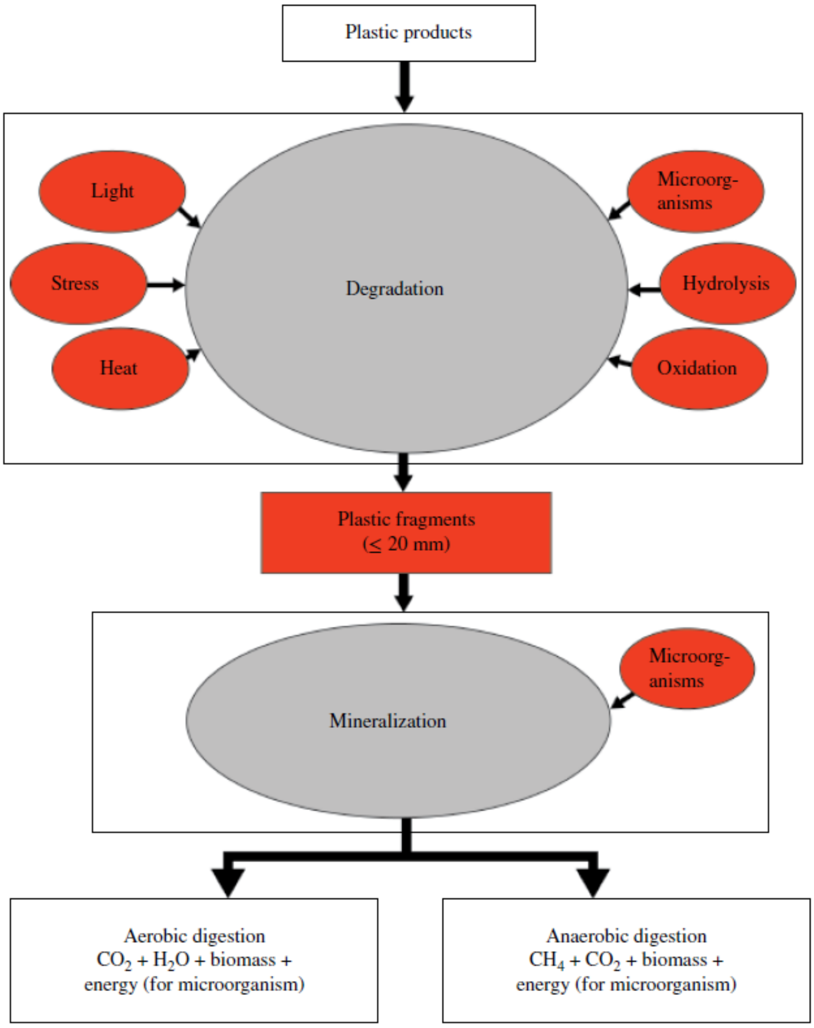
[47] McKeen, LW. (2018). Elastomers. The Effect of Sterilization Methods on Plastics and Elastomers, 305–351. doi:10.1016/b978-0-12-814511-1.00010-x.

[48] Pending reference from Plastic Recyclers.

[49] Andrady A.L., (2015).Degradation of Plastics in the Environment. Plastics and Environmental Sustainability, 145–184. doi:10.1002/9781119009405.ch6.

[50] Gewert,B., Plassmann, M.M., and MacLeod, M., (2015). Pathways for degradation of plastic polymers floating in the marine environment. Stockholm University, Department of Environmental Science & Analytical Chemistry (ACES), Stockholm, Sweden. Retrieved from: https://pubs.rsc.org/en/content/articlehtml/2015/em/c5em00207a.

33. Our knowledge on the degradation of plastics in the environment is limited, with no more than 20 years of studies in this area and there is a need for more research.[51] The rate of degradation can vary dramatically depending on the situation and type of plastic.[52] LDPE breaks down rapidly when it enters the marine environment, especially during the first week of exposure.[53] By contrast, HDPE and other plastics break down far less rapidly and often persist in the form of larger particles. Photodegradation of PP and PS is said to occur after approximately 3000 hours of exposure, compared to LDPE and HDPE which can occur after approximately 2000 hours. A study conducted by Weinstein et al. (2016) monitored the degradation rates of strips of HDPE, PP and extruded PS within a marsh environment with occasional water contact. After 8 weeks, biofilm was found on all samples and their layers of plastic film had begun to peel apart (delaminate).[54] When samples were examined under a microscope, the pitted surfaces resulting from the delamination led the research team to conclude this was a result of microplastic production and that this mechanism began to occur after an 8-week period.



[51] Fotopoulou, K. N., & Karapanagioti, H. K. (2017).Degradation of Various Plastics in the Environment. The Handbook of Environmental Chemistry. doi:10.1007/698_2017_11.

[52] Cheshire, A., Adler, E., Barbière, J. and Cohen, Y., (2009). UNEP/IOC Guidelines on survey and monitoring of marine litter, no. 186.

[53] Williams A. T. and Simmons, S. L. (1996).The degradation of plastic litter in rivers: Implications for beaches. J. Coast. Conserv., vol. 2, no. 1, pp. 63–72.

[54] Weinstein, J. E., Crocker, B. K., and Gray, A. D. (2016). From macroplastic to microplastic: Degradation of high-density polyethylene, polypropylene, and polystyrene in a salt marsh habitat. Environmental Toxicology and Chemistry, vol. 35, no. 7, pp. 1632–1640.

Figure 3: A schematic diagram of the biodegradation of a solid polymer showing the two main stages of primary abiotic degradation to embrittlement followed by biodegradation of fragmented residue. Adopted from[49]

3. Typical plastic additives

34. There are sub-groups of polymers within these general classifications. Very few basic polymers (also known as resins) are processed or used alone and most plastics are a blend of polymers and additives which provide the properties required for a particular application (see also Appendix 2). Thus: Plastics = Polymers + Additives.

35. Typical plastic additives include:

(a) Stabilizers: Polymer stabilizers prolong the lifetime of the polymer by suppressing degradation that results from UV-light, oxidation, and other phenomena. Typical stabilizers thus absorb UV light or function as antioxidants;

(b) Fillers: Many plastics contain fillers, to improve performance or reduce production costs. Typically, fillers are mica, talc, kaolin, clay, calcium carbonate, barium sulphate etc. Most fillers are relatively inert and inexpensive materials make the product cheaper by weight. Some fillers are more chemically active and are called reinforcing agents;

(c) Plasticizers: Plasticizers are, by mass, often the most abundant additives. Plasticizers impart plasticity (softness and flexibility) onto the material into which they are incorporated. Typical polymers without plasticizers are too rigid for certain applications;

(d) Colorants: Colorants (pigments, soluble azocolorants, processing oils etc.) are another common additive, though their weight contribution is small;

(e) Flame retardants as a stand-alone additive. It can be brominated flame retardants or short and medium chain chlorinated paraffins.

(f) Other functional additives: antistatic agents, antioxidants, lubricants, slip agents, curing agents, foaming agents, etc.

36. Typical plastic additives and concentration ranges in plastics are listed in Table 2(Specific chemical details will be added).

Table 2: Typical additives and concentration ranges in plastic materials. Adapted from[55]

Material	**Typical amount range (%w/w)**
Plasticisers	10-70*
Flame retardants	3–25 (for brominated)** and XX (inorganic)
Stabilisers, antioxidants and UV stabilizers	0.05–3
Heat stabilisers	0.5–3
Slip agents	0.1-3
Lubricants (internal and external)	0.1–3
Antistatics	0.1-1
Curing agents	0.1–2
Biocides	0.001-1
Colorants Soluble	0.25–5
Organic pigments	0.001–2.5

[55] 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.

Inorganic pigments	0.01–10
Fillers	up to 50
Reinforcements	Glass (15-30%)
Foaming agents ***	N/A

(*) 70 per cent applies to a small range of applications(**) (Hahladakis et al. 2018); (***) Foaming agents might or might not be present in waste depending on the foaming agent employed and the material created.

37. Some additives or plastics appear among the categories of wastes to be controlled included in the Annex I to the Basel Convention (see Table 3).

Table 3: Categories of wastes to be controlled included in Annex I to the Basel Convention that are relevant to plastics.

Category	Description	Remarks	Content (% by weight)
Y13	Waste from production, formulation and use of resins, latex, plasticisers, glues/adhesives	Resins (plastics without additives)	100% Resins
Y17	Wastes resulting from surface treatment of metals and plastics		
Y21	Hexavalent chromium compounds	Minor constituent of pigments	Chromium up to approx. 0.3%
Y23	Zinc compounds	Lubricant/stabilizer	Zinc < 0.2%
Y24	Arsenic; arsenic compounds	Biocides	…
Y26	Cadmium, cadmium compounds	E.g. cadmium sulphides or stearates used as pigments or heatstabilisers	Cadmium up to approx. 0.2%
Y27	Antimony, antinomy compounds	E.g. antimony trioxide used as co-synergist with halogenated flame retardants	Antimony, up to approx. 2%
Y29	Mercury; mercury compounds		
Y31	Lead, lead compounds	E.g. lead sulphates or phosphites used as heat or light stabilisers	Lead < 2.5%
Y36	Asbestos dust and fiber	(e.g. plastic asbestos slabs)	
Y45	Organo halogen compounds other than substances referred to in this Annex (e.g. Y39, Y41, Y42, Y43, Y44)	Halogenated polymers	The halogen content caught in the polymer/plastic matrix will vary with its structure

38. However, highly toxic additives used in plastics can create adverse effects to on human health and the environment. In addition, hazardous additives remain persistent in the environment, they may degrade and leach into the environment from landfill sites or as a result of being dumped or littered. Recent research has revealed that beached plastic found in on beaches in England contained high levels of chemical additives which were have been banned for some time in Europe. In addition, combustion of plastic waste can cause emissions of hazardous substances, for example, such as unintentional POPs such as dioxins. Table 4 provides list of substances of very high concern used as plastic additives.

Table 4: Substances of very high concern used as plastic additives
(ppm = parts per million, phr = parts per hundred rubber). Adapted from Wagner et al 2020.[56]

Additives	Purpose	Plastics	Common content
Hexabromocyclododecane (HBCD)[a]	Flame retardants	EPS, XPS in insulation HIPS in EEE	0.7–2.5% (EPS, XPS) 1–7% (HIPS) (UNEP 2015)
Tetrabromodiphenyl ether*	Flame retardant	as c-pentaBDE in: PUR, former printed circuit boards	0.5–5% (UNEP 2017a)
Pentabromodiphenyl ether	Flame retardant		N/A
Hexabromodiphenyl ether*	Flame retardant	as c-octaBDE in: ABS, HIPS, PBT, PA	12–18% (UNEP 2017a)
Heptabromodiphenyl ether*	Flame retardant		N/A
Decabromodiphenyl ether (DecaBDE)	Flame retardant	HIPS, PA, PO	5–16% (Buekens and Yang 2014)
Polybrominated biphenyls (PBBs) *	Flame retardant Plasticiser	ABS, foams, textiles, appliances	10% (International Programme on Chemical Safety 1994)
Diethylhexylphthalate (DEHP)	Plasticiser	PVC	30% (European Chemicals Bureau 2007)
Benzylbutylphthalate (BBP)	Plasticiser	PVC	5–30% (European Chemicals Bureau 2007)
Dibutyl phthalate (DBP)	Plasticiser	PVC	1,5% (Danish EPA 2009)
Diisobutyl phthalate (DIBP)	Plasticiser	PVC	Comparable to DBP (Gächter and Müller 1990)

Note: (*) The production of these substances was terminated, but they can still be found in old stocks as well as in recycled products.

39. Plasticisers. About 95% of all plasticisers used are dialkyl phthalates.[57] PVC, one of the most frequently used plastic materials, employs the highest quantities of additives, the most important of which are stabilisers and plasticisers.[58] About 80% of plasticisers are used in

[56] Wagner, S., Schlummer, M. (2020) Legacy additives in a circular economy of plastics: Current dilemma, policy analysis, and emerging countermeasures.

[57] OECD (2009). Emission Scenario document on plastic additives. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2004)8/rev1&doclanguage=en

[58] 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.

PVC while the remaining 20% are used in cellulose plastic.[59] The global use of plasticizers was 8.4 million tons in 2015[60] and is predicted to reach 9.75 million tons in 2024.[61]

40. Stabilisers can contain bisphenol A (BPA), lead (Pb) and cadmium (Cd) among others.[62] 50 % of all stabilisers are used in PVC.[63] Cadmium stabilisers have been used in several applications but are also increasingly being replaced. In addition, they have been voluntarily substituted since 2001 in the EU, and have been restricted under REACH since 2010. Lead stabilisers are used predominantly globally, but due to its severe health effects it has been entirely substituted in the EU for new products since the end of 2015 in favor of more environmentally acceptable stabilisers such as calcium or calcium-zinc stabilisers. These stabilizers can be found in particularly longer life applications such as EEE, PVC (window) profiles and pipes and fittings.

41. Some plastics contain flame retardants as additives. Additives include short, medium and long chain chlorinated paraffins; boric acid; brominated flame retardants with antimony (Sb) as synergist (e.g. Polybrominated diphenyl ethers (PBDEs); deca-BDE; tetrabromobisphenol A (TBBPA); phosphorous flame retardants, hexabromocyclododecane (HBCD),[64] and series of compounds known as Dechloranes.[65] Brominated chemicals are the most widely used flame retardants for plastics. BFRs are used in particular in electrical and electronic appliances, coatings, automotive parts, coated textiles, furniture, building materials and certain packaging consisting of or containing plastics.

42. Polybrominated diphenyl ethers (PBDEs or BDEs) are a class of synthetic additives that groups collectively hexabromodiphenyl, heptabromodiphenyl (hexa- and hepta-BDE), and tetrabromodiphenyl and pentabromodiphenyl ether (tetra- and pentaBDE), were included in Annex A of the Stockholm Convention before PBDE deca-BDE. All PBDEs have been used as flame retardants in plastics, particularly in EEE and automotive vehicles. These additives commercially have been marketed as c-PentaBDE, c-OctaBDE and c-decaBDE.

43. C-decaBDE is an additive flame retardant which has been used in a variety of applications such as plastics (90 % of all use), textiles, adhesives, sealants, coatings and inks.[66] Common applications for this additive are electrical and electronic products where it is found in computers, TVs, wires, cables, pipes and carpets.[67] Plastics containing c-decaBDE has also been used in vehicles and airplanes.[68] Decabromodiphenyl ether (BDE-209) of c-decaBDE with specific exemptions was added to the Stockholm Convention Annex A in 2017 (SC-8/10) for global elimination. Due to its long-range environmental transportation leading to significant adverse human health and environmental effects.[69] There are alternatives to c-decaBDE provided on the website of the Stockholm Convention.[70]

44. Hexabromodiphenyl (hexaBDE) and heptabromodiphenyl ether (heptaBDE) are flame retardants, which were used for material treatment rather than chemical mixture.[71] It was

[59] Ibid.

[60] https://www.plasticsinsight.com/global-plasticisers-market/.

[61] https://www.sciencedirect.com/science/article/pii/S0306374717301379?via%3Dihub.

[62] 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.

[63] 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 at: https://www.sciencedirect.com/science/article/pii/S030438941730763X, downloaded on 08/01/20.

[64] Ibid.

[65] Sverko, Ed., Tomy, G. T., Reiner, E. J., Li, Y., McCarry, B. E., Arnot, J. A., Law, R. J., Hites, R. A., (2011), Dechlorane Plus and Related Compounds in the Environment: A review. Environmental Science&Technology.

[66] UNEP/POPS/POPRC.11/10/Add.1.

[67] Ibid.

[68] Ibid.

[69] Ibid.

[70] http://chm.pops.int/Implementation/Alternatives/AlternativestoPOPs/ChemicalslistedinAnnexA/cdecaBDE/tabid/5985/Default.aspx.

[71] UNEP-POPS-NPOPS-GUID-StartupGuidance9POPs https://www.informea.org/en/startup-guidance-9-new-pops.

mainly used for acrylonitrile-butadiene-styrene (ABS) polymers. The main producers were industrial countries but according to the latest information these additives are no longer produced and so their release into the environment must be associated with past activities.[72]

45. Short-chained chlorinated paraffins have been used as flame retardants in plastics, textiles, plasticizer for polyvinyl chloride (PVC) and other plastics.[73] In 2017, it was agreed to list SCCP to the Stockholm Annex A for global elimination because of its potential for long-range environmental transport, leading to significant adverse human health and environmental effects. Recycling specifications are clarified in the guidelines (in progress). Alternatives to SCCPs in plastics are provided on the Stockholm Convention website.

46. Hexabromocyclododecane (HBCD) was a flame retardant used in expanded polystyrene (EPS) and extruded polystyrene (XPS) polymers. When these polymeric materials are used in packaging (e.g. for thermally insulating fast food), HBCD is unlikely to be used now. The prime example of EPS/XPS where HBCD to be found is in insulation material used in building and construction applications. HBCD containing waste may not be recycled unless a new technology enables the separation of the substance from the material. It was added to the Stockholm Convention Annex A for global elimination in 2013 (SC-6/13) due its long-range environmental transport and significant adverse human health and environmental effects.[74] Alternatives to Hexabromocyclododecane in plastics are provided on the Stockholm Convention website.

47. Additives are included in the polymer matrix, but are not necessarily reacted into it, leading to the potential for them to be released from a product. That matrix can be broken, for example at high temperatures (e.g., combustion) or pressures.

48. The composition of plastic waste does not only depend on the intrinsic composition of the different plastics included, but it may also contain certain impurities or contaminations. These may depend on the type of application of the plastic, the waste-generation, process or the way the plastic waste is collected. For example, plastic food packaging waste may still contain food residues, plastic film waste from agriculture may contain high percentages of soil and traces of pesticides and plastic waste from cables may contain residual metal and agrochemicals empty containers. When plastic waste is submitted to a treatment, there is a need to take into consideration both the intrinsic composition of plastic, chemical additives in the plastic, as well as the contamination with foreign agents (see also section III, H). Presence of these impurities and contaminations may influence the possibilities to manage the waste in an environmentally sound manner and should be addressed in an appropriate way. For this purpose, waste operators should have access to relevant and sufficient information about the intrinsic composition of plastics, in particular POPs listed in Stockholm Convention and hazardous substances identified by GHS, as well as the information on contaminants resulting from the use of plastics.

49. Colourants, and fillers used during plastic production are a challenge in plastic recycling. For instance, LDPE-film and PP-film that contain some colourants and/or fillers are not sorted out by the Near-infrared (NIR) detectors at mechanical sorting units.[75] Sorting is not the only problem; the extraction of colorants is also problematic.

II. Relevant provisions of the Basel Convention, Stockholm Convention and international linkages

A. Basel Convention

1. General provisions

50. The Basel Convention 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.

[72] Ibid.

[73] UNEP/CHW.14/INF/29/add.1- UNEP/POPS/COP.9/INF/28/Add.1.

[74] UNEP/POPS/POPRC.8/16/Add.3.

[75] Mepex Consult AS. (2017). Basic facts report on design for plastic packaging recyclability. Retrieved from: https://www.grontpunkt.no/media/2777/report-gpn-design-for-recycling-0704174.pdf downloaded on 24/01/20.

51. 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.

52. The scope of the Convention extends to two types of wastes subject to transboundary movement: "hazardous wastes", and "other wastes" that belong to any category contained in Annex II and require special consideration.

53. Hazardous wastes are defined in Article 1, paragraphs 1(a) and 1(b), of the Convention as "(a) wastes that belong to any category contained in Annex I, unless they do not possess any of the characteristics contained in Annex III ("List of hazardous characteristics"); and (b) wastes that are not covered under paragraph 1(a) but are defined as, or considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit." The definition of hazardous waste therefore incorporates domestic law such that a substance or object regarded as a hazardous waste in one country, but not another, is defined as hazardous waste under the Convention. The Convention also requires that Parties inform other Parties, through the Secretariat, of their national definitions (Article 3). Providing detailed and specific information on the national definitions of hazardous waste can promote compliance and avoid ambiguity concerning the applicability of national definitions.

54. To help Parties to distinguish hazardous wastes from non-hazardous wastes for the purpose of Article 1, paragraph 1 (a), two annexes have been added to the Convention. Annex VIII lists wastes considered to be hazardous according to Article 1, paragraph 1 (a), of the Convention unless they do not possess any of the characteristics of Annex III ("List of hazardous characteristics"). Annex IX lists wastes that are not covered by Article 1, paragraph 1 (a), unless they contain Annex I material to an extent that causes them to exhibit an Annex III characteristic.[76]

55. Paragraph 8 of Article 2 article defines the environmentally sound management 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."

56. 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."

57. Article 4, paragraphs 2 (a)-(e) and 2 (g), contains 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:

"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

[76] The glossary of terms was adopted by decision BC-13/2. Its focus is to provide guidance for further legal clarity in relation to the distinction between wastes and non-wastes and it includes definitions of terms and further explanations . The glossary of terms is available at: http://www.basel.int/Implementation/Publications/GuidanceManuals/tabid/2364/Default.aspx#.

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."

58. Hazardous wastes and other wastes should, as far as is compatible with environmentally sound and efficient management, be disposed of in the country where they were generated (preambular paragraph 8). Transboundary movements of such wastes from the country of their generation to any other country should be permitted only when conducted under conditions that do not endanger human health and the environment (preambular paragraph 9). In addition, transboundary movements of hazardous wastes and other wastes are permitted only if:

(a) Such wastes, if exported, are managed in an environmentally sound manner in the country of import or elsewhere (Article 4, paragraph 8); and

(b) One of the following conditions is met (Article 4, paragraph 9):

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

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

(iii) The transboundary movement in question is in accordance with other criteria decided by the parties.

59. Any transboundary movement of hazardous and other wastes is subject to prior written notification from the exporting country and prior written consent from the importing country and, if appropriate, transit countries (Article 6, paragraphs 1-4). Parties shall prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes (Article 4, paragraph 1 (b)). Some countries have implemented national prohibitions, inter alia following Decision III/1 of the Conference of the Parties, which contains an amendment to the Convention that entered into force on 5 December 2019 and bans the export of hazardous wastes from the countries listed in Annex VII (OECD and EU countries and Liechtenstein) to non-Annex VII countries. The Basel Convention also requires that information regarding any proposed transboundary movement of hazardous and other wastes be provided to the countries concerned using the accepted notification form (Article 4, paragraph 2 (f)) and that the approved shipment be accompanied by a movement document from the point at which the transboundary movement commences to the point of disposal (Article 4, paragraph 7 (c)).

60. Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards (Article 4, paragraph 7 (b)).[77]

61. When transboundary movements of hazardous and other wastes to which consent of the countries concerned has been given cannot be completed, the country of export shall ensure

[77] In this connection, the United Nations Recommendations on the Transport of Dangerous Goods Model Regulations (UNECE, 2015 – see appendix V, references) of 2015, or later versions, should be used.

that the wastes in question are taken back into the country of export if alternative arrangements cannot be made for their disposal in an environmentally sound manner (Article 8, first sentence). In the case of illegal traffic (as defined in Article 9, paragraph 1) as a result of conduct on the part of the exporter or generator, the country of export shall ensure that the wastes in question are:

(a) Taken back by the exporter or the generator or, if necessary, by itself into the country of export, or, if impracticable;

(b) Otherwise disposed of in accordance with the provisions of the Convention (Article 9, paragraph 2).

62. No transboundary movements of hazardous wastes and other wastes are permitted between a party and a non-party to the Convention (Article 4, paragraph 5) unless a bilateral, multilateral or regional arrangement exists, as required under Article 11 of the Convention.

63. Article 6 paragraph 5 provides that in instances where a transboundary movement of wastes where the wastes are legally defined as or considered to be hazardous wastes only:

(a) By the State of export, the requirements of paragraph 9 of Article 6 that apply to the importer or disposer and the State of import shall apply mutatis mutandis to the exporter and State of export, respectively;

(b) By the State of import, or by the States of import and transit which are Parties, the requirements of paragraphs 1, 3, 4 and 6 of Article 6 that apply to the exporter and State of export shall apply mutatis mutandis to the importer or disposer and State of import, respectively; or

(c) By any State of transit which is a Party, the provisions of paragraph 4 of Article 6 shall apply to such State.

2. Plastic waste related provisions

64. Through decision BC-14/12, the Conference of the Parties to the Basel Convention approved the following changes to three annexes to the Convention:

(a) Annex II (wastes that require special consideration, subject to the control procedure): addition of new 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[78,79]	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[80] • Plastic waste listed below, provided it is destined for recycling[81] in an environmentally sound manner and almost free from contamination and other types of wastes:[82] - Plastic waste almost exclusively[83] 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

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

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

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

[81] 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.

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

[83] In relation to “almost exclusively”, international and national specifications may offer a point of reference.

	- 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:[84] 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[85] of each material and in an environmentally sound manner and almost free from contamination and other types of wastes.

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

A3210[86]	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): addition of new entry B3011, replacing current entry B3010 as at 1 January 2021.

B3011[87]	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[81] in an environmentally sound manner and almost free from contamination and other types of wastes:[82] - Plastic waste almost exclusively[83] 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[83] 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[83] consisting of one of the following fluorinated polymers:[84] o Perfluoroethylene/propylene (FEP) o Perfluoroalkoxy alkanes: ▪ Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) ▪ Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA)

[84] Post-consumer wastes are excluded.

[85] 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.

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

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

	○ Polyvinylfluoride (PVF) ○ Polyvinylidenefluoride (PVDF) • Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling85 of each material and in an environmentally sound manner, and almost free from contamination and other types of wastes.[82]

65. The amendments entered into force on 24 March 2020, except for those Parties that declared by then that they were unable to accept them by notifying the Depository in writing.[88] The new entries to Annexes II, VIII and IX become effective on 1 January 2021.

66. Prior to 1 January 2021, for those Parties that have declared that they are unable to accept the amendments, plastic waste will fall within the scope of the Basel Convention provided they are classified as either:

(a) "Hazardous wastes", namely (a) wastes that belong to any category contained in Annex I (e.g. plastic wastes containing lead or halogenated organic compounds), unless they do not possess any of the characteristics (e.g. ecotoxic) contained in Annex III; and (b) wastes that are not covered under (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit; or

(b) "Other wastes", which include wastes collected from households or residues arising from the incineration of household wastes.

B. Stockholm Convention

1. General provisions

67. Article 1 defines the main objective of the Stockholm Convention on Persistent Organic Pollutants (POPs) to be the protection of human health and the environment from persistent organic pollutants (POP). Management of waste containing POPs should happen in a safe, efficient and environmentally sound manner. Parties to the Convention shall take measures to eliminate the chemicals in Annex A of the Convention and restrict the chemicals in Annex B. Article 6 defines measures to reduce or eliminate releases from wastes including products and articles upon becoming wastes, consisting of, containing or contaminated with a chemical listed either in Annex A or Annex B and wastes. Wastes consisting of, containing or contaminated with chemicals listed in Annex A, B or C shall not be permitted to be subjected to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of persistent organic pollutants

2. Plastic waste related provisions

68. Plastic may contain chemical additives and contaminates, some of which are subject to the Stockholm Convention on Persistent Organic Pollutants (POPs).

69. Polybromodiphenyl ethers:

(a) Hexa-BDE and hepta-BDE by the decision SC-4/14, tetra-BDE and penta-BDE by the decision SC-4/18, deca-BDE ether (commercial mixture, c-decaBDE) by the decision SC-8/10 with specific exemptions;

(b) Parties may allow the recycling of articles containing hexa-, hepta-, tetra, and/or pentabromodiphenyl ethers according to the Stockholm Convention. However, the following provisions apply:

(i) The recycling and final disposal is carried out in an environmentally sound manner and does not lead to recovery of [the PBDEs] for the purpose of their reuse;

(ii) Parties take steps to prevent exports of such articles that contain levels/ concentrations of [PBDEs] exceeding those permitted for the sale, use, import or manufacture of those articles within the territory of the Party;

(iii) The Party has notified the Secretariat of its intention to make use of this exemption;

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

(c) Provisions for ESM should be consulted in the guidelines (work in progress).

70. Short-chained chlorinated paraffins (SCCPs): By the decision SC-8/11, Conference of Parties of the Stockholm Convention listed SCCPs in Annex A. Provisions for ESM should be consulted in the guidelines (adopted BC-14/4).

71. Hexabromocyclododecane (HBCD): By the decision SC-6/13, Conference of Parties of the Stockholm Convention listed hexabromocyclododecane in Annex A with specific exemptions for production and use in expanded polystyrene and extruded polystyrene in buildings.

72. Perfluorooctane sulfonic acid (PFOS): By the decision SC-4/17, the Conference of Parties of the Stockholm Convention listed PFOS in the Annex B.

C. International linkages

1. Work under UNEA on marine plastic litter and microplastics

73. Concerns about global plastic littering, microplastics and the related risks are increasing. The negative effects on the marine and ocean environment has been globally agreed and governments are committing to reducing plastic pollution. Four resolutions on marine plastic litter and microplastics have been adopted by the United Nations Environmental Assembly (UNEA) on its sessions in 2014, 2016, 2017 and 2019 to address the challenges and the issue has also been addressed in separate resolutions, hereunder on waste management and on single-use plastics in 2019.

74. UNEA-1 res. 6 on "Marine plastic debris and microplastics"[89] formally brought the issue on UNEA's agenda and emphasized the challenges of plastic and microplastic, the need for urgent action and further information and research and encouraged multi-stakeholder engagement. It requested UNEP to undertake a study for presentation at UNEA-2, hereunder with recommendations on urgent actions. The comprehensive study was completed for UNEA-2[90] and one of its recommendations was to carry out an assessment of existing regulatory frameworks, institutional arrangements and mechanisms.

75. UNEA-2 res. 11 on "Marine plastic litter and microplastics"[91] addressed the challenges related to marine litter, hereunder issues of microplastic and nano-size particles, transport of plastic through freshwater systems, the slow degradation processes and the release and adsorption of chemicals such as POPs. It recognized the importance of cooperation between UNEP, conventions and international instruments as the International Convention for the Prevention of Pollution from Ships, the Basel Convention and SAICM and requested governments to identify the most significant sources, undertake cost-effective preventive measures, corporate with industry through public-private partnerships, phase out the use of primary microplastics and harmonize international definitions and standards for monitoring and assessment. The resolution also requested UNEP to undertake an assessment of the effectiveness of relevant governance strategies and regulatory frameworks. The assessment subsequently concluded that the existing global and regional legal landscape for addressing marine plastic litter is fragmented and uneven and outlined three possible policy paths forward, namely:[92]

(a) Option 1: Maintain status quo;

(b) Option 2: Revise and strengthen existing frameworks;

(c) Option 3: New global architecture with multilayered governance approach.

76. UNEA-3 res. 7 on "Marine litter and microplastics"[93] addressed the importance of preventive actions through waste minimization, environmentally sound waste management and actions in geographical areas with large sources of marine plastic litter and recognized that measures exist to provide cost-effective solutions. It encouraged common definitions,

[89] (UNEA-1 (2014). res. 6 "Marine plastic debris and microplastics".

[90] (UNEP (2016). Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.

[91] UNEA-2 (2016). res. 11 "Marine plastic litter and microplastics".

[92] UNEP (2017). Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches.

[93] UNEA-3 (2017). res. 7 "Marine litter and microplastics".

harmonized standards and methodologies for monitoring of plastic litter and the development of action plans for preventing marine litter, improved resource efficiency, recycling and avoidance of plastic containing chemicals of particular concern. It also noted the importance of industry and private sector collaboration.

77. The resolution 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 includes experts from UNEP member states, representatives from international and regional conventions and organizations and relevant stakeholders. The first AHEG meeting in May 2018 discussed policy measures and challenges for tackling marine plastic litter effectively and the adequacy of existing global governance frameworks,[94] while the second meeting in December 2018 addressed issues related to information, monitoring and governance and possibilities for new governance structures for marine plastic litter.[95]

78. UNEA-4 res. 6 on "Marine plastic litter and microplasticss"[96] took note of important developments within existing international agreements and organizations for addressing marine litter, such as the recommendations of the Open-ended Working Group of the Basel Convention on establishing a partnership on plastic waste and the adoption of an action plan by the IMO Marine Environment Protection Committee, supported by the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter to reduce marine plastic litter from ships. The resolution addresses development of indicators to harmonize monitoring, the need for effective monitoring of sources, quantities and impacts of marine litter and invited member states to promote environmentally sound waste management and marine plastic litter recovery. The resolution also establishes a multi-stakeholder platform within UNEP to serve as a forum for governments, industry, academia, civil society and other stakeholders to share experiences, coordinate action, serve as repository for assessments, practical guidance materials and actions plans and raise awareness.

79. The UNEA-4 resolution took into account the outcomes of the AHEG and in particular the need to increase coordination and synergies between existing mechanisms and enhance cooperation and governance to address marine litter challenges. It decided to extend the mandate of the AHEG to UNEA-5 and requested the expert group to take stock of existing activities and analyze the effectiveness of existing and potential response options and governance.

80. UNEP-4 furthermore passed two separate resolutions related to plastic litter, namely UNEA-4 res. 7 on "Environmentally sound management of waste",[97] which includes an invitation to member states to establish standards for food-grade plastics to minimize the risk of toxins getting into foods, strengthen monitoring activities, reduce microplastics, strengthen legislation to prohibit open burning of plastics and support plastic recycling, and UNEA-4 res. 9 on "Addressing single-use plastic products pollution"[98] that encourages member states to develop and implement actions to address environmental impact of single-use plastic products, identify 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.

2. SAICM

81. The Strategic Approach to International Chemical Management (SAICM) is a voluntary global policy instrument setup by the World Summit on Sustainable Development in 2002. It focuses on the measures to achieve the Sustainable Development Goals related to sound chemical and waste management by 2020. Their work is governed by the following documents: Dubai declaration; Overall Policy Strategy; and Overall Orientation and Guidance.

[94] UNEP/AHEG (2018a). Report of the first meeting of the ad hoc open-ended expert group on marine litter and microplastics, available online 16-04-2020 at https://papersmart.unon.org/resolution/first-adhoc-oeeg.

[95] UNEP/AHEG (2018b). Report of the second meeting of the ad hoc open-ended expert group on marine litter and microplastic, available online 16-04-2020 at https://papersmart.unon.org/resolution/second-adhoc-oeeg.

[96] UNEA-4 (2019a). res. 6 "Marine plastic litter and microplastics".

[97] UNEA-4 (2019b). res. 7 "Environmentally sound management of waste".

[98] UNEA-4 (2019c). res. 9 "Addressing single-use plastic products pollution".

82. It is evident that achieving the goals of sound chemical and waste management by 2020 will be very difficult and that continuation of the process is required. SAICM shares common goals with multinational environmental agreements such as Basel, Rotterdam and Stockholm Conventions and sets the next working period beyond 2020. The recent Conference of Parties to Basel, Rotterdam and Stockholm Conventions requested the Secretariat (BC-14/21; SC-9/19; RC-9/9) to continue to enhance cooperation and coordination with relevant initiatives including SAICM.

(Plastic waste related provisions will be added.)

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

A. General considerations

83. Environmentally sound management (ESM) in the context of waste is a broad policy concept that is understood and implemented in various ways by different countries, policy processes and stakeholders. Its foundation was laid out in Chapter 21 of Agenda 21, a global action plan of the United Nations, and carried on in the 2030 Agenda for Sustainable Development, which measure progress with the Sustainable Development Goals (SDGs). Environmentally sound management of waste is one of the underlying principles of the Basel Convention. The Organisation for Economic Co-operation and Development (OECD) also follows the ESM provisions and recommendations.

84. In the context of the Basel Convention, the framework for the environmentally sound management of hazardous wastes and other wastes ("ESM framework")[99] establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM.

85. Under this framework, environmentally sound management is defined 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." This definition comprises all harm including harm linked to plastic waste debris in the marine environment and possible anthropogenic pressures on climate. Moreover, the ESM framework outlines the main elements that should be considered during the implementation or evaluation processes. These building blocks below are directly relevant to the present guidelines on environmentally sound management of plastic waste:

(a) Regulatory matters (e.g., compliance, enforcement, consistency and complementarity);

(b) Facility-related matters (e.g., regarding construction and infrastructure);

(c) Waste-related matters (e.g., prevention, collection, sorting, pre-treatment, treatment, storage, transport, downstream management);

(d) Resource and process efficiency;

(e) Environmental protection matters (e.g., prevention of pollution, emission limit values to air, water and soil);

(f) Occupational safety and health (OSH) matters (e.g., regarding liability and emergency response);

(g) Organizational matters (e.g., valid licence or permit, monitoring, record keeping, information to be provided to authorities, aftercare, environmental insurance, management abilities and training level and applicable EMS);

(h) Transparency (publicly accessible information), due diligence and accountability;

86. Innovation and research and development (e.g., through funding, information exchange and cooperation with academia and others).

[99] UNEP/CHW.11/3/Add.1/Rev.1

87. The ESM framework follows the latest waste hierarchy defined by UNEP[100] giving priority to waste prevention, minimization followed by re-use, recycling, (energy) recovery and final dispoal. Such a strategy includes an integrated approach to waste management (Figure 4) with priority to waste prevention and minimization.

88. In addition, the ESM of plastic wastes includes a full range of recycling and recovery options of variable environmental impacts and benefits: material recycling (mechanical recycling or feedstock/chemical recycling), incineration with energy recovery, use as an alternative fuel source replacing traditional (petrochemical) fuels for power generation or for material production. Post-user plastic waste can present unique challenges of identification, separation and contamination, especially in countries with inadequate infrastructure. However, where sufficient volumes of plastic waste are separately collected and sorted in to specific waste streams recycling is more likely to be achieved. Waste that is unsuitable for recycling could be sent to energy recovery or sent for disposal if there is no suitable waste recovery option.

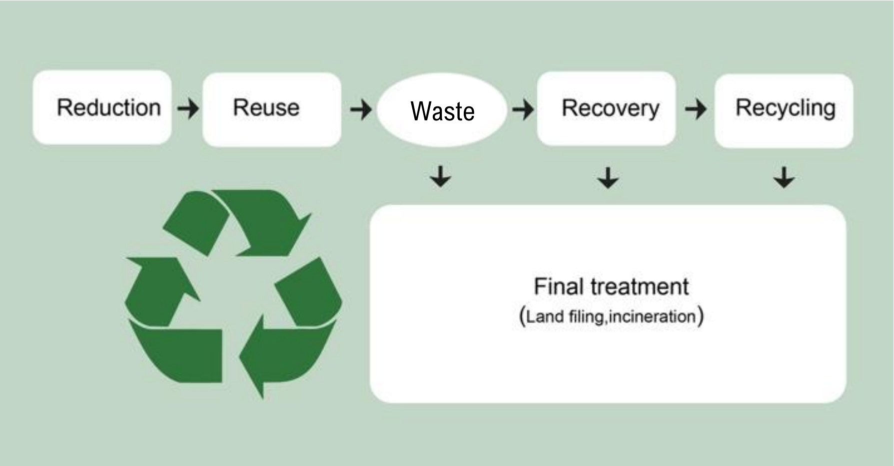


Figure 4: Integrated approach to waste management

B. Legislative and regulatory framework

89. Parties to the Basel Convention should assess their national and subnational strategies and policies, legislation and implementation tools and instruments for compliance with the Convention and with their obligations, including those that pertain to ESM of plastic wastes.

90. 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 sound management of plastic wastes, including provisions for inspections and for establishing penalties for violations (e.g. on illegal traffic).

91. Such tools should enable competent authorities to monitor whether plastic waste management facilities have obtained all the necessary permits and can demonstrate due diligence in compliance, for example in plastic recycling facilities, to avoid all possible plastic leakages. The authorities should also provide oversight of the actors involved in plastic waste management (e.g. collectors, transporters and recyclers) to ensure that the collection, transportation, storage and treatment of wastes are carried out in conditions providing protection for the environment and human health.

92. 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

[100] UNEP (2015). Global Waste Management Outlook.

agreements are discussed in technical assistance documents.[101] Parties should follow these documents to develop legislation to ensure ESM of plastic wastes.

93. The legislation should cover plastic product policies to increase recycling rates of plastic materials or stimulate sustainable use. Where extended producer responsibility schemes are not covered on a voluntary basis by industry or in non-legislative agreements between industry sectors and governments, the legislation can provide for them.

94. In addition, Parties should apply a systems thinking approach to harmonizing and developing policy frameworks related to plastics and their fate. Such an approach addresses the root causes of the problem and takes a long-term perspective that considers the long-lasting consequences of plastic in the environment, including the marine environment.

95. Plastic wastes must be understood as a part of broader waste generation. Plastic wastes are often mixed with and contaminated by other wastes that could undermine their environmentally sound management and/or degrade their recycling value. Until now mixed and contaminated plastic wastes have often been destined for final disposal, energy recovery or low-cost technology recycling that triggers adverse health and environmental impacts. Therefore, plastic wastes management should be seen in the context of wider municipal solid waste (MSW) management.

1. Resource recovery

96. Prevention, minimization, reuse and recycling are the preferred steps in the waste management hierarchy, and the recovery of valuable material should be seen in a broader picture of commodity markets where virgin plastics compete with recyclable materials.[102]

97. Countries should work towards a greater level of resource recovery and recycling to increase the overall plastic recycling rates, currently estimated at 20 percent annually. Providing the necessary strategies, policies and procedures for fostering demand for recovered plastic waste could make recovered plastic competitive with virgin materials. Phasing out plastic wastes from landfills may help, as could enhancing the uptake of secondary raw materials and promoting non-toxic material cycles by aligning rules between virgin and secondary materials.

98. Waste prevention or reduction involves both upstream alterations in product design, including use of alternative materials or technologies, as well as alterations in consumer habits. In Europe, product design has focused more on energy efficiency and less on material recyclability, durability or reparability,[103] yet eco-design determines almost 80 percent of a product's environmental impact.[104] Design strategies that emphasize recyclability, durability or reparability serve two useful objectives – the process produces less waste and by using constituents that are less hazardous, generates waste that is less hazardous. Waste prevention is a strategy that prevents waste and its associated risks from being produced in the first place, and in addition, minimizes leakages into the terrestrial and marine environment.

99. Effective policies on hazardous substances can result in a reduction of substances of concern – and encourage the introduction of innovative, safer additives to plastics. Using calcium as a replacement for cadmium and lead compounds as stabilizers in plastics, for example, will make these plastics more readily recyclable. In addition, current food industry legislation concerning food contact materials (plastic packaging) often lacks harmonization with wider regulations applied to harmful substances, including those classified as substances

[101] Further guidance on Basel Convention regulatory frameworks can be found in the following documents: *Manual for the Implementation of the Basel Convention* (UNEP, 2015f) and *Basel Convention: Guide to the Control System* (UNEP, 2015g). 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, 2014).

[102] Gu, F., Wang, J., Guo, J., Fan, Y. (2020) Dynamic linkages between international oil price, plastic stock index and recycle plastic markets in China.

[103] European Commission (2018c), COMMISSION STAFF WORKING DOCUMENT accompanying the document COM (2018) 29 on the implementation of the circular economy package: options to address the interface between chemical, product and waste legislation, European Commission.

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

of concern or of very high concern.[105] For instance, the plasticizer DEHP contained in flexible PVC is subject to restrictions and authorization in the EU under REACH, but is often managed as non-hazardous waste[106] and has been authorized for use in plastic food contact materials.[107]

100. Bans and phase-outs on specific plastic products have already been introduced in several countries, as have regulatory measures applying to specific uses (e.g., cosmetics, single-use plastics, shopping and grocery bags etc.).

101. Standards applied to plastic products can be utilized to ensure certain properties related to quality and plastic production process. Several standards related to plastics have been developed (e.g., ISO 83.080.01 on Plastics).[108]

102. Countries need to adopt policies and procedures to prevent and minimize plastic waste generation. Regulations could focus on:

(a) Reducing packaging for e-commerce items;

(b) Adopting policies to reduce excessive packaging and single-use plastic products (including the reduction of plastic shopping and grocery bags, utensils, plates, cups and straws, etc.) in favor of more sustainable alternatives, considering LCA;

(c) Promoting best practices of producers and consumers to avoid spillage and extend the life of products;

(d) Increasing the amount of recycled material in plastic products and packaging (including ensuring and encouraging use of recyclable packaging);

(e) Implementing product standards (e.g. design) and specifications; promoting labelling and identification of products;

(f) Removing difficult-to-recycle materials such as polyvinyl chloride (PVC) and expanded polystyrene (EPS);

(g) Prohibiting use of hazardous additives in plastics;

(h) Financially supporting (grants or donation system) the development of recycling, sorting and collecting of plastic waste;

(i) Providing education campaigns on waste management.

2. End-of waste criteria

103. Various end-of-waste criteria have been introduced to determine the point at which a material need no longer be classified as waste after it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in accordance with the following conditions:

(a) The substance or object is commonly used for specific purposes;

(b) A market or demand exists for such a substance or object;

(c) The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;

(d) The use of the substance or object will not lead to overall adverse environmental or human health impacts.

3. Transboundary movement requirements[109]

104. Y48 (in Annex II) and A3210 (in Annex VIII) are categorized as other wastes and hazardous waste respectively and should, as far as is compatible with their ESM, be disposed

[105] Safe Food Advocacy Europe (2016), “SAFE Newsletter 15”, Vol. 5.

[106] European Commission (2018c), COMMISSION STAFF WORKING DOCUMENT accompanying the document COM (2018) 29 on the implementation of the circular economy package: options to address the interface between chemical, product and waste legislation, European Commission.

[107] European Food Safety Authority. (2018). Scientific panel on Food Contac Materials (FCMs), Enzymes, Flavourings and Processing Aids (CEF).

[108] https://www.iso.org/ics/83.080.01/x/.

[109] This applies to Parties to the Basel Convention.

of in the country where they were generated. Transboundary movements of such wastes are permitted only under the following conditions in accordance with the Basel Convention:

(a) If conducted under conditions that do not endanger human health and the environment;

(b) If exports are managed in an environmentally sound manner in the country of import or elsewhere;

(c) 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;

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

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

105. 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 prohibit 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.

106. The Basel Convention also requires that information regarding any proposed hazardous and other waste transboundary movement 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.[110]

107. When a transboundary movement of hazardous 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).

108. 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 arrangement exists as required under Article 11 of the Convention. From 5 December 2019, the Basel Convention Ban Amendment also states that the OECD, EU and Lichtenstein will not export hazardous waste to non-OECD countries.[111]

109. B3011 (in Annex IX) is out of control of Basel Convention, therefore the transboundary movement do not require prior written consent from the importing countries. In relation to “almost free from contamination and other types of wastes” regulated by B3011, international and national specifications may offer a point of reference.

4. Specifications for containers, equipment, bulk containers and storage sites containing plastic wastes[112]

110. 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.

[110] In this connection, the United Nations Recommendations on the Transport of Dangerous Goods (Model Regulations) of 2003 (UNECE, 2003a) or later versions should be used.

[111] http://www.basel.int/Default.aspx?tabid=8120.

[112] UNEP/CHW.12/5/Add.2/Rev.1 Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POP.

111. Parties should ensure that containers that may be transported to another country meet international standards such as those established by the International Air Transport Association (IATA), the International Maritime Organization (IMO) and the International Organization for Standardization (ISO).

5. Health and safety[113]

112. A legislative approach should be taken to secure protection of workers, both in the formal and informal sectors. Communities co-located where plastic wastes are stored and processed should be protected from possible exposure to hazardous substances from plastic waste and measures should be taken to reduce the risk of fires. Provisions within storage and recycling facilities should include requirements for the proper labelling of relevant products and wastes and the identification of appropriate and safe disposal methods. While neither the Basel or the Stockholm Convention specifically require Parties to have legislation in place to protect the health and safety of those that work in waste storage and recycling facilities, the protection of human health underpins the objectives of both Conventions.

113. Most countries have existing health and safety provisions for workers either in general labour legislation or in specialized human health or environmental legislation. Parties should examine their existing legislation to ensure that that informal sector workers, and communities located close to sites where plastic wastes are stored and processed are also protected, that hazards are adequately addressed and the that relevant aspects of international agreements are integrated into such legislation. Health and safety is a relatively mature field and a great deal of guidance and literature is available to assist in the planning and revision of legislation, policy and technical guidance.

6. Requirements for plastic waste treatment and disposal facilities

114. Most countries have legislation in place that require 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 to minimize harm to human health and the environment, and to comply with the specific requirements of the Basel and Stockholm Conventions.

7. General requirement for public participation

115. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. Public participation in the permitting or approval process for waste storage or waste treatment facilities as referred to in section III, J below may be addressed in legislation or policy.

8. Other legislative controls

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

(a) Siting provisions and requirements relative to the storage, handling, collection and transport of wastes;

(b) Decommissioning requirements, 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;

(c) 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; and

[113] Ibid.

(iv) Obligations to ensure best-practice management systems to prevent pellet loss with a supply-chain approach, including requirements for annual reporting and regular third-party auditing and verification after the accident.

(d) 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 (NDCs) for parties to the Paris Agreement.

9. Extended producer's responsibility

117. Extended Producer Responsibility (EPR) systems for plastic and plastic packaging have been introduced in many industrialized countries. EPR is an approach that promotes reuse, recycling, energy recovery, and eco-friendly disposal of waste. EPR assigns the responsibility of disposal of specific wastes to the producer of the goods. For example, disposal of plastic packaging used for food items, consumer goods, and water bottles are in some cases assigned to the manufacturers of consumer goods or those than place these goods on the market.

118. At the core of EPR lies a closed loop approach to managing products, whereby waste generated from a product is used to produce another product. In this sense, EPR programs can support more efficient waste collection schemes, enhance diversion of plastic waste from final disposal, increase recycling and increase the value of the waste. Where applied effectively well, EPR programs can encourage manufacturers and distributors of products and packaging to improve their design to reduce waste generation.

119. EPR can help improve the implementation of legislation, contributing to broader environmental and circular economy objectives, including reducing natural resource depletion, GHG emissions and waste leakage to terrestrial and marine environments.

120. EPR schemes can shift the burden on public budgets for municipal waste management to the industry responsible for producing the waste and can contribute to increased cost efficiency in waste collection and recycling systems. Moreover, EPR schemes contribute to the design of reusable plastic products or the generation of separated, high quality secondary raw materials, supporting market development and contributing to resource security. Fee modulation within EPR has the potential to encourage producers towards eco-design.[114]

121. Existing EPR schemes may be implemented using a range of different instruments. Around the world, the most common approach is various forms of take-back requirements (almost three-quarters of all schemes); while advance disposal fees (ADF) and deposit refund schemes (DRS) account for most of the rest.[115]

(a) Advanced disposal fees (ADF) are fees levied on individual products at the point of purchase, based on estimated costs of collection and treatment. The fees may be used to finance end-of-life management of the products in question[116] (OECD, 2016).

(b) Deposit Refund Systems (DRS) add a surcharge on individual products at the point of purchase. The entire fee, or a portion of it, is refundable when the used product is returned to the point of sale or at specified waste management sites. The aim is to encourage take-back of the used product rather than to cover costs. DRS can exist as voluntary systems or as part of legislative agreements with producers.

(c) Product take-back requirements commonly involve establishing both mandatory or voluntary recycling and collection targets for specific products or materials and assigning responsibility to producers or retailers for end-of-life management to achieve these targets. In some cases, product take-back is arranged on a business-to-business basis.

[114] Watkins, E., Gionfra, S., Schweitzer, J. P., Pantzar, M., Janssens, C., & ten Brink, P. (2017). EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging. *Institute for European Environmental Policy (IEEP)*. Available at: https://ieep.eu/uploads/articles/attachments/47856bb4-4af9-47a6-a710-7af0fe8b3518/Policy%20options%20brief%20EPR%20price%20modulation%20IEEP%20Nov%202017%20final.pdf?v=63677462325.

[115] Kaffine, D and O'Reilly, P. (2015). What Have We Learned About Extended Producer Responsibility in the Past Decade? A Survey of the Recent EPR Economic Literature. OECD.

[116] OECD (2016) Extended Producer Responsibility - Guidance for efficient waste management. OECD, Paris.

122. The type of responsibility varies between producer responsible organizations (PROs). The most commonly PROs take the form of financial and organizational obligations. The simple financial responsibility includes usage of fees from producers to set up and manage a take back system such as the Belgian scheme for industrial packaging or the UK system of electronic Packaging Waste Recovery Notes (ePRNs).[117] Another possibility is to go through direct reimbursement contracts with municipalities as in the Czech Republic, Denmark and France.[118]

123. Organizational responsibilities include full or partial involvement. In terms of full organizational responsibility, the PRO is responsible for the organization of the collection and recycling of packaging waste. In partial responsibility, usually municipalities are responsible for collection and sorting of waste and PRO reimburses them and sells for example sorted material (Ref required). It should however be noted that organizational PROs promote the establishment of a buying monopoly of waste collection and treatment services with potential impacts on the sound management of waste.

124. Products including plastic such as EEE, cars and C&Ds are in most developing economies under relevant EPR schemes. In a few countries such as France, Italy, Spain, Sweden EPR has been introduced for agricultural plastic waste, as well. Other products such as toys, houseware, furniture, packaging, agricultural plastics, fishnet and carpets can also be covered by EPR schemes.

125. Components of strong EPR programs for plastic waste can include:

(a) Clear definitions of products covered;

(b) Mandatory compliance with legally binding requirements;

(c) Strong enforcement provisions including dissuasive fines for non-compliance and the ability for public oversight;

(d) Responsibility with producers furthest up the chain that is under the jurisdiction of the government (this may be the manufacturer, importer, distributor, brand owner, etc.), as the entity that can have the most influence on product design;

(e) Measurable targets for plastic waste prevention and reduction, for reusability, durability and repairability of plastic products, for exclusion of toxic additives, and for mechanical recycling;

(f) Protection for existing informal waste collection workers;

(g) Public education program;

(h) Publicly-accessible reporting;

(i) Financial responsibility borne by producers.

126. Further guidance on EPR is available in the revised draft practical manuals on extended producer responsibility and financing systems for environmentally sound management (UNEP/CHW.14/5/Add.1).[119]

C. Waste prevention and minimization

127. The prevention and minimization of plastic wastes are the first and most important steps in the overall waste management hierarchy.[120] One of the multiple benefits of waste prevention and minimization is the reduction in the release of plastic waste into the terrestrial and marine environments. 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".

[117] Watkins, E., Gionfra, S., Schweitzer, J.-P., Pantzar, M., Janssens, C., ten Brink, P. (2017). EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging. Institute for European Environmental Policy, Brussels, Belgium. 57pp.

[118] European Commission, (2014). Development of Guidance on Extended Producer Responsibility (EPR). Final Report. Available at: http://ec.europa.eu/ environment/waste/pdf/target_review/Guidance%20on%20EPR%20-%20Final% 20Report.pdf.

[119] UNEP (2019) Revised draft practical manuals on extended producer responsibility and financing systems for environmentally sound management (UNEP/CHW.14/5/Add.1).

[120] UNEP/CHW.13/4/Add.1.

128. According to the framework for the ESM of hazardous wastes and other wastes, the need to manage wastes and/or the risks and costs associated waste management can be reduced by not generating wastes and by ensuring that generated wastes are less hazardous.[121]

129. According to the Basel ESM framework for the environmentally sound management of hazardous wastes and other wastes "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 or other materials.

130. Waste generators and significant downstream industrial users of plastic products and articles could be required to develop waste management plans.

131. The effectiveness of waste-management efforts requires multi stakeholder involvement in the development of waste-management plans with a strong emphasis on prevention and minimization, in partnership with waste generators, significant downstream industrial users and civil society.

132. Elements of a waste prevention and minimization programme that applies also for plastic wastes are included 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/CHW.13/INF/11/Rev.1). Furthermore, actions on waste prevention and minimization that applies also for plastic wastes are included in the draft guidance document on the environmentally sound management of household wastes (under preparation, Basel Secretariat).

133. Plastic waste prevention and minimization should be addressed in a life-cycle perspective approach including measures and procedures in: reduction of plastic materials in production phase; product redesign to ensure that hazardous substances are avoided; and increasing reusability and recyclability of plastic products, including the incorporation of recycled plastics.

134. Retailers and brand owners, where possible, should control excess packaging and labelling, removing difficult-to-recycle materials and non-detected black plastic, ensuring and encouraging use of recyclable packaging and packaging that was made from recycled materials and reducing packaging for e-commerce.

135. Measures to reduce the use of plastic and other single-use shopping bags and single use products for waste prevention in retail stores shall be taken when sustainable alternatives exist. For example, countries that have water service infrastructure in place and can provide safe and high-quality tap water, measures and campaigns to reduce the use of PET bottles, could enhance reduction of plastic wastes. Other policy instruments on waste prevention are provided in Table 5.

136. Local authorities should promote waste prevention-based community building through communication where local commerce and industries, as well as consumers, are visible. See more in Chapter III.J.

Table 5: Policy instruments on waste prevention

Policy instruments	Waste prevention instruments
Regulatory	Landfill ban, incineration bans, plastic bag bans, disposable cutlery bans, to-go or single-use product ban
Market-based	PAYT, landfill tax, incineration taxes and fees, extended producer responsibility (EPR) principle. Recycling insurance, taxes on products (packaging, plastic bags)
Information	Awareness campaigns, school campaigns, procurement guidelines, information exchange platforms
Voluntary	Eco-design of products, designing out waste, bottleless water

[121] UNEP/CHW.11/3/Add.1/Rev.1.

D. Identification and inventories

1. Identification of plastic wastes sources

137. Plastic wastes are categorised into two main categories: pre-consumer and post-consumer wastes. (See Figure 5).

138. Most plastic wastes come from the post-consumer market. Post-consumer wastes are found in municipal solid waste (MSW) but are also generated in the following economic sectors: distribution and large industry, agriculture, construction and demolition, automotive, electronics and electrical, textiles and white goods. Plastic packaging has the largest share (35.8%) in the market of plastic products and generally has a short lifetime. Packaging is also one of the main plastic waste generation sector accounting for 46% of plastic waste generation (see Appendix 7).

139. In recent years, greater attention has been given to plastic wastes that become litter in the environment. An increasing number of clean-up initiatives are taking place across the globe, many of these are linked to the clean-up of the marine environment. The latest report from Ocean Conservancy reveals that the most found ítems on beaches are post-consumer plastic.[122] Plastic from land-based and ocean-based activities should be collected and brought back for environmentally sound waste management of waste.

140. Pre-consumer plastic wastes, which generally account for less than 10%, are generated during the manufacture of virgin plastic from raw materials (oil, natural gas, salt, etc.) and from the conversion of plastics into plastic products. For the flow sheet of plastics production and recycling see appendix 2.

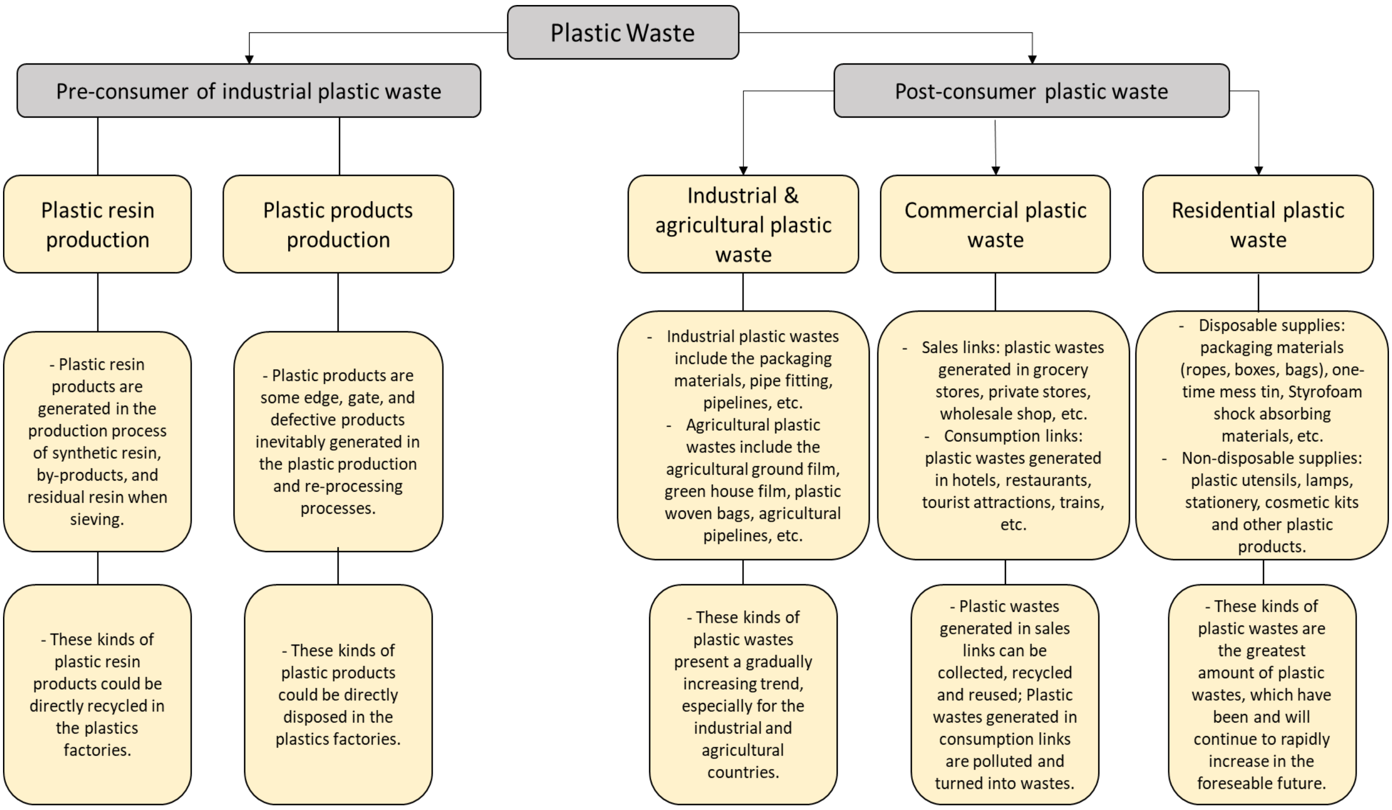


Figure 5: Classification of plastic waste[123]

[122] Ocean Conservancy (2019). The Beach and Beyond. Ocean Conservancy.

[123] Yang, S. S.; Brandon, A. M.; Xing, D. F.; Yang, J.; Pang, J. W.; Criddle, C. S.; Ren, N. Q.; Wu, W. M.,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. Retrieved from: https://iopscience.iop.org/article/10.1088/1755-1315/150/1/012005/pdf.

2. Identification of plastic wastes sources

(a) Pre -consumer plastic waste

141. The wastes generated by resin manufacturers are often reusable. These can often be recovered and sold, although some intermediate grinding or other processing may be required. However, there are sources of plastic waste which are unsuitable as raw material for any process. This may be the case with:

(a) Composite materials;

(b) Plastics that are too degraded and which cannot achieve the required properties for either processing or as a by-product;

(c) Contaminated wastes that exceed a manufacturers specification (e.g. excessive floor sweepings).

142. Conversion industries are the usual source of these wastes.

143. Pre consumer plastic waste may be generated during polymer production, polymer compounding, plastic convention, and plastic component assembly or installation. Appendix 6 lists the typical types and quantities of plastic wastes for different manufacturing processes.

144. Polymer production. While the industry strives to produce only first-grade material, it is likely that a small proportion of base polymer will be off-specification and unsuitable for the intended customer. This polymer may nevertheless find a proper usage in other specified applications, where it:

(a) Meets regulatory limitations on monomer content and/or contaminants;

(b) Is blended with appropriate non-hazardous additives and complies with local regulations;

(c) Contains additives necessary to match the end- application as long as such mixing does not render the material hazardous or difficult to handle in an environmentally sound manner.

145. Polymer compounding. The process of compounding polymers with additives may give rise to material outside the specification required by one customer but suitable for other applications. The exact formulation or recipe of the quantities of resin(s) and different additives may not have been respected, and a non-specification material may have been used. This will result in the wrong color, hardness or processing characteristics. Before recycling it is essential to ensure that such polymer compounds:

(a) Are of known composition, suitable for the new application;

(b) Are processed under appropriate conditions for that material;

(c) Meet regulatory (composition) requirements for the proposed application;

(d) Are single grades or a known mixture of closely related grades;

(e) Are not hazardous or does not render the final end-product difficult to handle in an environmentally sound manner.

146. Plastics convention (transformation). Converting factories (e.g., moulding and extrusion) may produce waste materials from start-up, shut down and running conditions which cannot be re-used on-site because of quality or specification limitations. These waste materials might need to be shredded before being reused.

147. Such materials may nevertheless be used in other applications. It is essential to ensure that such wastes:

(a) Are of known composition;

(b) Are used in an appropriate application;

(c) Are processed under appropriate conditions for that formulation;

(d) Are not contaminated or degraded so as to make them unsuitable for processing;

(e) Are a single grade or a mixture of closely related grades, conditioned to the standards required for related virgin material;

(f) Do not contain hazardous chemicals.

148. Plastic component assembly or installation. Some plastics are supplied as semi-finished goods. When they are processed, there are scraps or off-cuts, which can be recycled into the same or alternative applications. For example, the off-cuts from PVC-U window frame assembly can be recycled into new window frames or into conduit and ducting. Off-cuts from the forming of cups from PS sheet can be recycled into cups for example. The installation of PVC or PE pipes, ducting or rainwater goods will also give rise to recyclable off-cut material, which can be recycled into pipes or ducting. Provided that they do not contain hazardous chemicals such as lead and phthalates.

149. Such recyclates will perform best when:

(a) The wastes are sorted into individual types free from dirt;

(b) Foam materials are kept separate from solid grades;

(c) Processing conditions are chosen to take account of the processing history of the waste.

150. Overall, pre-user plastic waste tends to be well utilized with the exception of pellet loss. Plastic pellets leakage from plastics are the second largest direct source of ocean microplastic pollution. As a result of poor handling and transportation practices, pellets are routinely spilt and lost to the environment at every stage of the plastic supply chain (e.g. during production, storage, loading and unloading, transport, and conversion into plastic products, including recycling). Voluntary schemes to address pellet loss such as Operation Clean Sweep have developed best practice but have had low uptake, pointing to the need for binding obligations to prevent pellet loss.

(b) Post-consumer plastic waste

151. While pre-consumer wastes are typically clean, segregated from other resins, physically close to the point where they can be recycled and well characterized in terms of origin and physical properties, this is generally not the case for post-consumer plastic wastes. In addition, post-consumer plastic wastes come in various forms, including composite materials, mixtures of different plastics or mixtures of plastics and non-plastic wastes. To be recycled, the plastic(s) must first be cleaned and separated from other waste materials; additional value can be obtained with further separation into homogeneous materials. These factors contribute to the increased costs and need for appropriate infrastructure for recycling post-consumer wastes when compared to pre-consumer wastes.

152. An increasing number of countries are enacting legislation that requires that end- of-life plastics be recovered for recycling. The return of end-of- life components to suppliers may also form part of commercial transactions. Extracting the plastics from equipment at the end of its life may be difficult and expensive but part of such materials can be recycled. On the other hand, some plastic wastes cannot be recycled due to the types of plastic polymers or additives used, or because they are composed of composite materials.

153. Post-consumer plastic waste may fall into one of the following categories:

(a) Plastic bottles, pots, tubs and trays, which are mainly found in the household waste stream;

(b) Plastic film such as plastic shopping bags, rubbish bags, bubble wrap, and plastic or stretch wrap. Plastic films compose a broad category of materials that can be relatively simple or complex, depending on the demand of a particular product or package. It can be clear or colored, printed or plain, single or multi-layered, thus the only thing that all plastic film really has in common is that it is flexible in nature;

(c) Rigid plastics, such as crates, pipes, and mouldings. These products are made from a variety of different polymer types and can come from almost any source, from hospitals and caterers to agriculture and large industry;

(d) Plastic foams, such as expanded polystyrene (EPS) packaging;

(e) Flexible plastics, such as strapping and cable sheathing. These products are made from a variety of different polymer types and can come from a variety of sources;

(f) Plastic waste components of e waste.

154. Each source of waste has its own specificity, such as:

(a) Municipal solid waste (MSW) and agricultural plastic waste are geographically more dispersed than distribution waste;

(b) Agriculture sector wastes have a better material homogeneity than MSW or automotive waste. However, agriculture plastic wastes have a high risk of contamination by hazardous pesticides and could constitute hazardous plastic waste;

(c) Construction/demolition waste or MSW are more likely to be significantly contaminated with non-target materials or substances than electrical and electronics plastic waste.

(i) Municipal solid waste (Household waste)

155. According to the Global Waste Management Outlook, municipal solid waste appears to be among the three major waste generating sectors together with construction and demolishing waste, and industrial waste.[124] Municipal waste accounts for 21 %. The plastic waste fraction typically accounts for between 8 to 12 % of the total municipal solid waste.[125] There may be small variations influenced by socio-economic factors dictating overall waste generation, but in general these variations are lower than in other waste streams (e.g. organic). Even at first glance the numbers may look low, but the unintended release of plastic waste into the environment is significant. UNEP estimates an average of 8.28 Mt each year, with a distribution of 64% and 36% of macro- and microplastics, respectively.[126]

156. Municipal solid waste is classified as Y46 (wastes collected from households) in Annex II of the Basel Convention and is regarded as 'a waste requiring special consideration'. While it is not directly the concern of these guidelines, and will be covered by the guidelines on the environmentally sound management of household wastes, (under preparation, Basel Secretariat) some Parties have legislation in place which requires households and businesses to separate and collect plastics for recycling, which would otherwise be part of MSW. Furthermore, in some countries plastics wastes can be and are separated from commingled MSW. These plastic wastes must be managed in an ESM manner in the country where they were generated; and may only be subjected to TBMs in line with relevant Basel Convention provisions.

157. The major plastic polymers predominantly found in household waste are Polyethylene (PE), Polyethylene Terephthalate (PET), Polypropylene (PP), Polystyrene (PS), and Polyvinyl Chloride (PVC). In general, household plastic wastes consist of a mixture of various materials which are difficult to identify. The composition of plastics in MSW is influenced by factors such as culture, climate, economic development (measure of GDP), geolocation, and energy sources and therefore varies from country to country (See also Appendix 8). High-income countries have the propensity to increase packaging material wastes generation combined, by proportion, such as paper, glass, metal and plastics to organic waste particularly in MSW composition.[127]

158. Examples of end-of- life municipal plastic wastes include:

(a) Potable water and drainage pipes: P E-LD, PE-HD, PVC-P, cross-link HDPE & PEX (on the line of Computer & keyboard frames;

(b) Cable/cable insulation: P E-LD, PE-HD, PVC-P PTFE, PP;

(c) Window frames and construction off-cuts: PVC-U, PVC-E;

[124] These data exclude agricultural and forestry and mining and quarrying wastes.

[125] UNEP, ISWA (2015) Global Waste Management Outlook. ISBN: 978-92-807-3479-9

[126] UN Environment (2018). Mapping of global plastics value chain and plastics losses to the environment (with a particular focus on marine environment). Ryberg, M., Laurent, A., Hauschild, M. United Nations Environment Programme. Nairobi, Kenya.

[127] Shehu, S. (2017). Separation of plastic waste from mixed waste: Existing and emerging sorting technologies performance and possibilities of increased recycling rate with Finland as case study.

(d) Computer enclosures & keyboard frames: PS, ABS and PC-ABS (on the line of Computer & keyboard frames);

(e) Bottles: PET, PE-HD, PVC-U;

(f) Packaging film: PP, PE-LD, PE-HD, PVC -U, PVC –P;

(g) WEEE (in general): ABS, HIPS, PP, PC-ABS, PMMA, PC, PA , others;[128]

(h) Textiles (e.g clothing and carpets): [text to be added]

159. WEEE. Electrical and electronic goods in the home such as cookers, washing machines, refrigerators, freezers, and consumer electronics.

160. One of the most significant constitutes of WEEE is plastic. Plastic wastes in WEEE irrespective of the region or country in average is 21%.[129] Average composition of WEEE in plastics is provided in Appendix 8.

161. WEEE are covered in its interim Basel Convention technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention. The Mobile Phone Partnership Initiative under the Basel Convention produced guidelines on the environmentally sound management of used and end-of-life mobile phones. In addition, the Basel Convention Partnership for Action on Computing Equipment (PACE) has published guidance on the environmentally sound management of used and end-of-life computing equipment.

162. Textiles. Plastic waste in the textile sector accounts for almost 15% of global plastic waste generation and may come from residential, industrial, commercial and institutional sources. Residential textile waste is mainly clothing and home textiles such as towels, curtains, bedding, which consists of synthetic and natural fibres.[130]

(ii) Commercial and large industrial plastic wastes

163. This sector also produces large amounts of plastic wastes. It includes bags, drums and containers for the food and chemical industries, packaging films, discarded industrial equipment, crates, etc. In this sector, the collection of well-defined materials is often easier than from households. WEEE from the industrial sector is also a source of plastics waste.

(iii) Agriculture plastic waste

164. Out of the 265 million tonnes of plastic produced in 2010 worldwide, 2% was used in agriculture.[131]

165. The agricultural sector uses PP, PE, PVC plastics these generally have a short to medium lifespan. Examples of short-lived products are plastic film for covering greenhouses and fertilizer sacks as well as mulch films and fumigation films. Products with a medium life span are irrigation pipes and valves, containers, drums and tanks.

(iv) Construction / demolition plastic waste

166. The construction and demolition (C&D) sector typically uses plastics in applications for much longer than other sectors, making it difficult to estimate the waste generated based on consumption. It has been estimated that general building and construction sector uses about 19% of nonfiber plastic, most of which is PVC.[132] Although the building and construction sector is a big consumer of plastic material, it may generate a relatively small proportion of the

[128] Pending to add reference.

[129] United Nations University. (2007). 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE). Final Report.

[130] Ellen MacArthur Foundation, 2017, A New Textile Economy: Redesigning Fashion's Future. Retrieved from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/A-New-Textiles-Economy_Full-Report.pdf.

[131] Briassoulis, D., Babou, E., Hiskakis, M., Scarascia, G., Picuno, P., Guarde, D., Dejean, C., 2013. Review, mapping and analysis of the agricultural plastic waste generation and consolidation in Europe. Waste Management & Research, 31(12): 1262-1278.

[132] Geyer, R., Jambeck, J. R., Law, K.L., (2017), Production, use, and fate of all plastics ever made. Science Advances. Sci.Adv. 2017; 3:e1700782.

total waste produced. For example, in Europe, the building and construction sector uses about 21 % of plastic, but it only accounts for 6% of the plastic waste generated per year.[133] It can be explained by durability of the material. An example of composition of plastics in C&D waste is provided in appendix 8.

(v) Waste Electrical and Electronic Equipment (WEEE)

167. WEEE is collected separately in the territories of several parties. Such WEEE can be obtained from households, companies, and institutions. The material is typically shredded and materials are sorted to obtain several material streams (e.g. ferrous metals, non-ferrous metals, glass). Plastics are normally concentrated in the shredder light- or fluff- fraction. The unprocessed fluff fraction is, likely to contain POPs.

168. POPs are typically brominated flame retardants (BFRs) and are not uniformly distributed throughout the fluff fraction, with flakes of plastics not containing BFRs and flakes containing BFRs. The addition of BFRs to plastics material results in an increase in density, which can be used to separate the flakes. Frequently, the fluff fraction is separated at density ~1.1 g/cm³ in a pre-float facility to obtain a 40 – 60% fraction <1.1 g/cm³ that is almost completely free of BFRs containing PE/PP/PS/ABS and can be further processed for recycling and a fraction of >1.1 g/cm³ that is a concentrate of the BFRs and other materials that needs to be destroyed unless new technology is developed that could concentrate the POPs further."[134]

(vi) End of Life Vehicles (ELV)

169. End of Life Vehicles (ELV) frequency contain plastics that can be recycled. Several parties have enacted specific legislation on ELV including recycling and recovery targets. Typically, such legislation requires specific de-pollution operations (e.g. the drainage of fluids and the removal of lead acid batteries). Vehicles are subsequently shredded and the resulting materials are sorted in a similar manner to WEEE. At the moment of writing, the fluff fraction is likely to contain POP BFRs and density sorting can result in a fraction almost free of POP BFRs and a fraction with a POP BFR concentrate.

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

170. The ASTM International Resin Identification Coding (RIC) System, is a set of symbols appearing on plastic products that identify the plastic resin out of which the product is made[135] (See Appendix 3).

171. Basel Convention provides classification of plastic wastes based on resins at Annex IX.

4. Identification of hazardous and non-hazardous plastic wastes [text to be added]

5. Contaminants

172. Contaminants are unwanted and off-specification materials present within a collection of plastic waste. Contaminants can be classified in two groups: plastics and non-plastic material components that are not the same material and therefore unwanted but that may be separated and directed to a separate recycling stream;, and non-plastic material components that are detrimental for recycling, unusable for further manufacturing or hazardous and thus must be appropriately disposed. Contamination levels in plastic wastes can affect their classification under the Basel Convention under either listing Y48 (Annex II) or B3011 (Annex IX), with implications for prior-informed consent during TBMs.

6. Tests to identify plastics

173. There are tests that can be carried out to identify the characteristics of plastic products but these require some standard laboratory equipment. "Simple Methods for Identification of Plastics" by Dietrich Braun (Hanser Verlag ISBN 0-02-949260-2 for English text) provide a selection of proven procedures which enable the technicians, engineers, and also the technical customer service representatives to identify unknown plastics, e. g., for purposes of quality control or plastics recycling.

[133] Bio Intelligence Service (2011). Plastic waste in the environment.

[134] Pending reference.

[135] ASTM Plastics Committee Releases Major Revisions to Resin Identification Code (RIC) Standard, https://www.astm.org.

7. Specifications

174. Specifications are industry-wide standards for material content and quality that are developed according to customer needs and other market factors. They identify the primary material, tolerance for non-primary material and intolerances for contamination. For example, the ISRI Specification[136] for PET Bottles demands that the consignment contain more than 94% of PET Bottles; closures (lids and rings) are acceptable, HDPE and LDPE are allowed to consist of the remaining 6% because they can be sorted out and sent to a separate facility for recycling, but PVC, wood, oils and hazardous materials are never allowed because they would be detrimental to the recycling of the PET bottles.

8. Inventories

175. Inventories can be an important tool for identifying, quantifying and characterizing wastes.

176. When developing an inventory, priority should be given to the identification of important waste streams (e.g., hazardous plastic wastes). National inventories may be used:

(a) To establish a baseline quantity of plastic products, articles and wastes;

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

(c) To obtain the accurate information needed to draw up plans for site stabilization;

(d) To assist with the preparation of emergency response plans;

(e) To track progress towards minimizing and phasing out specific plastic waste streams (e.g. single-use plastics).

177. 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.[137] 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.

E. Monitoring (including sampling and analysis)

178. 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 plastics in some waste streams, degree of contamination of the plastic wastes, as well as the presence and concentration of hazardous substance within plastic wastes. Effective monitoring enables managers to see whether a waste management operation is functioning in accordance with its design and complying with relevant environmental regulations.

179. Environmental monitoring may also be necessary to ensure operations are complying with required standards and to ensure that hazardous substances are not released into the environment. Monitoring and surveillance serve as elements for identifying and tracking environmental concerns and human health risks. 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 marine plastic litter can provide information on the extent and impact of plastic pollution and the effectiveness of policy measures related to plastic waste management.

180. The information obtained from the monitoring should be used to:

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

(b) Ensure that different types of hazardous and other wastes are properly managed by the waste management operation;

(c) Identify potential issues relating to possible release or exposure and determine whether adjustments to the management approach might be appropriate.

[136] https://www.isri.org/recycling-commodities/scrap-specifications-circular.

[137] UNEP. 2015e. Methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention. Available from: www.basel.int.

181. Monitoring procedures are composed of sampling and analysis, which 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 time span of the programme. They should also be subjected to rigorous quality assurance and quality control measures. Mistakes in sampling or analysis, or deviation from standard operational procedures, can result in meaningless data or even programme-damaging data.

182. Each party should identify its 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.

183. Different analytical methods can be used depending on the purpose of the sampling or monitoring activity and the physical form of the waste. For information on good laboratory practices the OECD series (OECD, various years) and the Handbook on Good Laboratory Practices (WHO , 2009) may be consulted.

1. Sampling

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

185. Standardized 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 quality assurance 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 transport and storage (before analysis);

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

186. In order to assure the sampling quality, qualified staff should be appointed and sampling should comply with specific national legislation, where it exists, or with international regulations and standards, which can include the following:

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

(b) Application of well-established sampling procedures;[138]

(c) Establishment of quality assurance and quality control (QA/QC) procedures.

187. Locations of sampling concerning plastic pollution and potential leakages of pollutant in the environment could be:

(a) Points of collection of plastic wastes and/or prior to sorting;

[138] Such as procedures developed by ISO, the American Society for Testing and Materials (ASTM), the European Union, 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 sorting and material recovery facilities;

(c) Ports of reception of imported plastic wastes;

(d) Input and output of re-processing facilities.

188. Types of waste matrices typically sampled pollutants and leakages 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 starndards:

(a) Liquids:

(i) Wastewater from plastic recycling, thermal and chemical recovery, incineration (with or without energy recovery, including co-incineration) as well from the sewage treatment plants (inlet and outlet);

(ii) Leachate from dumpsites and landfills;

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

(b) Solids:

(i) Consumer articles and products.

(ii) Stockpiles, products and formulations containing contaminates;

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

(iv) Soil, (including in areas surrounding incinerators given potential for fly ash contamination), sediment (including in water bodies near plastic waste treatment plants), rubble and compost;

(c) Gases:

(i) Air (indoor);

(ii) Air (emissions);

(d) Biomarkers & human exposure sampling:

(i) Eggs of free-range hens raised outdoors in the vicinity of incinerators and thermal recovery plants, for dioxins, furans and brominated flame-retardants;

(ii) Trout and other fatty fish in water bodies in the vicinity of plastic waste treatment plants;

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

189. Sampling should prioritize the investigation of pollutants specifically associated with plastic wastes and their disposal, including but not limited to the following. Detail can be determined following the specific national legislation or international regulations and standards:

(a) Macroplastics and microplastics;

(b) Bisphenols and phthalates;

(c) Brominated flame-retardants;

(d) Dioxins and furans;

(e) Heavy metals (including mercury, lead and cadmium);

(f) Polycyclic aromatic hydrocarbons (PAHs);

(g) Volatile organic compounds (VOCs);

(h) Polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB);

(i) Particulate matter;

(j) Nitrogen oxide, carbon monoxide, carbon dioxide, methane ;

(k) Acid gases (including sulphur dioxide and hydrogen chloride);

(l) Aldehydes.

2. Analysis (more text to be added)

(a) Analysis according to standards;

(b) Reporting in accordance with regulation(s).

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

190. Handling, separation, collection, packaging, compaction, transportation and storage are important in the management of plastic waste. Procedures and processes for managing hazardous wastes should be considered for these activities to prevent spills and leaks resulting in worker exposure, releases to the environment or exposure of the community.

1. Handling

191. Plastic waste - whether hazardous or not - needs to be handled appropriately to minimise risk to human health and the environment. Waste from polymer manufacturing and blending processes is often in the form of powders or granulates contained in bulk bags or containers. Post-consumer waste is likely to be in bulky form and may require balling or bagging for shipment to waste processors. Employees should be informed on the health risks associated with exposure to plastic waste, and the levels of pollutants they may be exposed to; 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. An example of detailed guidance on the environmentally sound and safe handling provided to managers of plastics sorting and recycling enterprises in the UK is illustrated in Appendix 5.

2. Separation at source

192. Source separation of generated plastic wastes is an essential step in managing plastic waste and can determines downstream pre-treatment, sorting and recovery operations. Source separation entails the sorting of plastics waste from other wastes before collection as opposed to separation from other wastes after collection. In general, plastics recyclate derived from source separated waste have a higher economic value.

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

194. Source separation of post-consumer plastic packaging waste may be performed in:

(a) Mono-material separation systems where plastic is 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 recyclables (e.g. metals and plastics) are collected together.

195. The collection of clean plastic waste at source (source separation) should be a priority and should be enhanced in order to increase recycling, improve environmental performance and managing costs.

196. If source separation is not an option (e.g., in very dense urban environment addition of separate collection infrastructure can be difficult), plastic wastes can also be sorted out of mixed MSW. Such plastis wastes may be 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 post-sorting operations can have a strong odour, particularly when the original mixed MSW contained green waste, limiting the possibility to use the material in consumer applications.

197. The highest quality recyclate is typically collected from deposit-and-return systems (DRS), followed by kerbside/door-to-door collection, drop-off systems, and, lastly, post-sorting of MSW. In the EU PET bottles, currently, collected from DRS eventually result in a recyclate that has a greater economic value (roughly 40% more) than virgin material, while recyclate originating from post-sorting of MSW typically results in recyclate that are about 20 – 40% less valuable than virgin."[139]

3. Collection

198. Care should be taken in establishing and operating waste collection programmes in order to increase the efficiency of the waste collection systems.

(a) Household plastic wastes collection schemes

199. 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

200. These schemes utilises the following collection systems for the collection of plastic waste:

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

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

(c) Bring system (Drop-off) system: Consumers bring their plastic waste such as plastic bottles and plastic bags to a certain collection site. While this is generally for enhancing collection of plastic bottles, there are current efforts that plastic bags and wraps, like grocery bags, zipper sandwich bags, and some cereal bags to be dropped off at depots and stores. From the technical point of view, bring systems plastic collection remains quite simple and homogeneous;

(d) Civic amenities / Civic amenity site: Typically enclosed and sometimes staffed collection sites, where recyclables and generally also hazardous waste, bulky waste, waste of electrical and electronic equipment (WEEE), construction waste, etc. from households can be brought by citizens;

(e) Deposit-and-return system (DRS): typically applied on beverage bottles. 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 more than 40 regions worldwide with great results.[140] The DRS could be expanded to other plastic packaging.

201. The instructions given to households and the scope of plastic waste collected differ from one case to another as well as effectiveness of each collection system (see Table 6).

Table 6: Overview of collection systems in place in the EU-28 capital cities[141]

Collection type	Plastic collected
Door-to-door (single fraction)	9 kg/cap Highest:32
Co-migled	6 kg/cap Highest:12

[139] Pending reference.

[140] https://zerowasteeurope.eu/wp-content/uploads/2019/07/2019_07_23_zwe_drs_manifesto.pdf.

[141] BiPRO/CRI 2015, Assessment of separate collection schemes in the 28 capitals of the EU, Final report, November 2015.

Bring points	7 kg/cap Highest:26
Civic amenity sites	1 kg/cap

202. In some countries, kerbside and door-to-door collection refer to bottles only or cover all “dry and clean” plastic packaging waste. Kerbside and door-to-door collection is more diversified and varied in frequency (weekly, monthly), in equipment used, i.e. the classical MSW collection trucks, compartmentalized trucks, and in instructions to the households, such as separate collection of plastics or collection of mixed recyclables (see Table 7).

203. Experience in developed countries demonstrate that many factors can influence the cost of selective collection. The dissemination of quantities to collect and the low density of plastics are the most important factors explaining the high collection costs of plastic wastes compared with other recyclables such as paper and glass. In addition, the level of participation of the population and their receptivity to selective collection schemes has been found to be very influential. Public participation in MSW plastic waste collection schemes will influence both the quantity and the quality of the plastic waste collected and thus the cost per recyclable ton of recyclables. Public awareness campaigns constitute an important element in assuring the participation of the population.

Table 7: Comparison of drop- off and kerbside collection

(Source: Elements for a cost-effective plastic waste management in the EU, EC, 1997)

	Bring system	**Kerbside/ Door to door**
Principles	Households bring plastic bottles and/or plastic packagingto street containers	Plastics are collected regularly at each door
Scope	Plastic bottles only or plastic packaging	Plastic bottles or all plastic packaging
Techniques	Almost standardized: Containers + collection trucks	Various: • Collection in binds or bags • Plastics collected separately or with other recyclables • Separate or simultaneous collection of recyclables and residual waste (compartmentalised trucks) • Different frequencies
Main factors influencing costs	• Low density plastic • Participation of the population • Local context (urban, rural)	
	Density of containers	• Collection frequency • Collection of plastic alone or mixed with other recyclables
Advantages	• The concentration of plastics is initiated by the households and therefore makes collection easier • Costs limited mainly to containers implantation	• Good quality of service • High recovery rate
Constraints	Low recovery rate Visual impact	High collection cost

204. Collection costs can be different between one case to another. (text to be provided)

205. The possibility of organizing selective collection schemes depends mainly on the quantities of plastic waste collected separately and the frequency of collection. Collection

schemes will be much more difficult for drop- off systems than for kerbside systems and in rural areas compared to urban or semi- urban areas. In rural areas the visual impact of drop-off systems may be a concern. When selective collection is organized with compartmentalised trucks, both fractions (plastic waste and residual household wastes) can be collected simultaneously.

206. In countries with developing economies a drop off system sometimes is more beneficial and effective than door-to-door collection depending on the terrain and the ability of the government to implement collection. Door-to-door collection specifically for plastics only may be costly, time consuming and may not be feasible in many places.

207. In many countries, the informal sector makes a significant contribution to the collection of household wastes, including plastic wastes. The informal sector contributes environmental and economic benefits by diverting recyclable plastic wastes from landfill or other disposal options, and provides valuable materials to the reuse and recycling industries. The Basel Convention details guidance on the incorporation of ESM practices in the informal sector, and on integrating the informal waste sector, in the revised draft guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP/CHW.14/INF/8, 2019).

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

208. Collection of industrial and commercial waste is usually organized with large drop- off containers rented by the waste producer and collected regularly by private operators. The same system applies to different kinds of waste: industrial waste, commercial packaging waste, and even agricultural waste (drop-off depot containers would be located in the cooperatives, for instance). In many countries, however, agricultural plastic waste may be buried or burnt directly in fields, or dumped in the open environment, instead of being collected for ESM.

209. Industrial and commercial waste streams, tend to be of a higher quality compared to household packaging stream. Recovery of wasteplastics from these sectore is well-established in some countries and has been relatively stable over recent decades.

210. Plastic waste originatin g from maritime activities such as aquaculture and fisheries (e.g., fishing nets) should be brought back on land and delivered at ports (reference to port-back facilities).

(c) Waste Electrical and Electronic Equipment

211. WEEE are collected separately by some parties. Often these collection systems are administered, at least partially, under an EPR system. For example, collection points for batteries, small domestic appliances, large domestic appliances, and fluorescent tube lamps can be collected in the Netherlands at collection points that have been introduced in many shops and are financed by the producers through the foundation WECYCLE, which in turn is financed by producers. Alternatively, at the point of sale to the final consumer the retailers can be obliged to take back an article of a similar category (e.g., when the new washing machine is delivered the old defect one is taken back). Furthermore, business disposing of WEEE can be obliged to do so in an environmentally sound manner by mandating that it goes to certified/designated waste treatment facility.

212. The collection systems should be designed in such a manner that the WEEE is ending up at specialized treatment facilities that are able to handle such material in an environmentally sound manner, taking due considerations for other guidance and standards for the treatment of such waste. Plastics fractions obtained from this treatment should likewise be directed to specialized plastics recyclers that are able to treat such waste in an environmentally sound manner.

(d) End of Life Vehicles

213. Several parties have enacted special End of Life Vehicles (ELV), designed to govern the collection and environmentally sound management of ELVs. Such processing will give rise to plastic fractions that need to be treated with due consideration for the potential presence of POPs. Collection systems should extend to the capture of these plastics fractions from ELV processing and direct these to specialized waste treatment facilities.

214. Care should be taken to prevent leakages from (especially developed) countries, in the form of export of ELV as used vehicles. A manner to prevent such leakages could be the

provision of a reimbursement per ELV delivered to specialized waste treatment facilities. The financing of such a reimbursement can be done through an EPR mechanism".

4. Packaging

215. Packaging of plastic wastes falls into two categories: packaging or baling for transport and for storage.

216. Packaging for transport of hazardous plastic wastes is often controlled by national dangerous goods transportation legislation. For packaging specifications for transport, the reader should consult reference materials published by IATA, IMO, UNECE, GHS and national governments.

217. Plastic wastes, whether hazardous or not, should be properly packed or baled for ease of transport and as a safety measure to reduce the risk of leaks and spills. For other plastics waste baling might be appropriate, however if the size is inappropriate transport in big bags or closed bulk containers can be an appropriate measure for transport.

218. Some general precepts for the packaging of plastic wastes for storage are as follows:

(a) Plastic wastes should be properly packaged. In most cases packaging that is acceptable for transport is suitable for storage, unless more stringent storage requirements are specified;

(b) Such wastes in their original product containers are generally safe for storage if the packaging is in good condition;

(c) Plastic wastes should never be stored in product containers that were not intended to contain such wastes or that have labels on them that incorrectly identify their contents;

(d) Containers that are deteriorating or are deemed to be 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;

5. Compaction

219. Plastic wastes from semi-finished product conversion, packaging wastes and other wastes may be bulky and may contain more than one type of plastic waste. For economical transport and storage some compaction may be necessary. The most common compaction processes are baling and shredding.

220. 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 waste-water and other wastes from the shredding.

221. Wherever possible, sorting into single product streams should be undertaken before the compaction process, however, some markets will not accept shredded material because quality standards beyond common sorting processes are required.

222. mixed plastics residues should only be shredded if there is an assured application for the mixed product or if a post-shredding sorting system is available to produce single material streams of acceptable quality.

223. The following points should be noted for environmentally sound and safe operations:

(a) Shredders must 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 must 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 must be dried and/or conditioned to the specification used by downstream industry/waste processors.

224. Baling is suitable for component, film and bottle wastes. It has the advantage that post-compaction sorting is a simple low-technology process. Safe and efficient baling requires attention to the following:

(a) The size and form of the bale should be optimised for its transport and reuse;

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

(c) Compacted bales contain a great deal of energy. The rust-resistant steel or polyester strapping must 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) Under-compacted bales may be unstable;

(f) Bales should only be handled by means of a pallet truck or fork- lift truck.

6. Transportation

225. The transport of baled or shredded plastics residues requires considerable attention to the stability and protection of the load. Bales and bags 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 plastics waste, particular care should be taken to ensure the safety of workers.

7. Storage

226. Polymers degrade with prolonged exposure to ultraviolet light, resulting in the deterioration of the physicochemical properties of the plastic. Ideally, all plastic waste destined for recycling in shredded or baled form should be stored on clean concrete floors. If plastic waste is stored indoors, fire-prevention system should be available to prevent fires and ease firefighting. If plastic waste is stored outdoors, then it should be protected from contamination and weather damage by means of tarpaulins or black polyethylene film. Contamination of plastics from dust and dirt can be avoided by the use of pallets. Stacking should be strictly limited in height (e.g. no more than 3 bales high) to to reduce the risk of bales moving or falling.

227. Plastic wastes stored outside should be covered with a UV-protective material. The need for protection varies according to virgin polymer as indicated in Table 8.

Table 8: UV Exposure and Degradation of Resins/Virgin Polymer

Resins/Virgin Polymer	Maximum Unprotected Outside Storage
PET	6 months
PE-HD	1 month
PVC	6 months
PE-LD	1 month
PP	1 month
PS PTFE	6 months Indefinite

228. 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 many wide 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 on Health and Safety). These precautions are similar to those for many other materials.

8. Shipping

229. Before transboundary movements, appropriate procedures under the Basel Convention and other international agreements should be fulfilled.

230. For all transboundary movements of plastic wastes, plastic wastes should be appropriately contained and packaged, such as in the form of bales for compacted materials or containers or in bags for shredded material, to protect the materials in transit and prevent spillage into the open environment, including in the event of container loss.

231. In addition, consignments should be clearly labelled with the type of material, the point of origin and the name of a responsible contact at the dispatching organization. Customer Should received documentation prior to shipment which includes, the type or types of plastic wastes to be shipped and the appropriate handling instructions

232. Packaging and shipments should be carried out according to the Guidelines of the UNCETDG. Generally, plastics and plastic packaging do not need to be labelled according to UNCETDG guidelines because they are not considered as dangerous.

233. In case of transboundary movements, additional attention have to be paid (see paragraphs 112 -116).

G. Environmentally sound disposal

1. Recycling of plastic wastes

(a) General considerations on recycling

234. Plastics can be challenging to recycle because of the wide variety of uses, additives, and blends that are used in a multitude of products.[142] According to different international standards, plastic recycling and recovery activities include three categories: primary (mechanical reprocessing into a product with equivalent properties), secondary (mechanical reprocessing into products requiring lower properties) and tertiary (recovery of chemical constitutes) (Table 9). Primary recycling is often referred to as closed-loop recycling, and secondary recycling as downgrading. Tertiary recycling is either described as chemical or feedstock recycling and applies when the polymer is de-polymerized to its chemical constituents.[143]

Table 9: Categories and definitions of plastic waste recycling and recovery activities. Adopted from[Error! Bookmark not defined.]

ASTM D5033 definitions	ISO 15270:2008 definitions	equivalent terms
primary recycling	mechanical recycling	closed-loop recycling
secondary recycling	mechanical recycling	downgrading
tertiary recycling	chemical recycling	feedstock recycling

235. Plastic waste recycling can be hindered by other methods of plastic waste treatment. For example plastics waste to energy may become competitive in financial terms and reduce plastic waste recycling.[144,145,146]

236. In order to extract more value from end-of-life plastic, there is a need to promote methods of improving the quality of the recovered and recycled materials as well as supporting and improving markets for secondary materials. This may be achieved by an combination of the following interventions.

(b) Physical/Mechanical Recycling

237. Mechanical recycling refers to the processing of plastic wastes by physical means, it is one of the most popular methods employed around the world to treat thermoplastic polymers such as PP, PE and PET. Thermoplastics polymers are superior to thermosetting polymers in

[142] J. N. Hahladakis, C. A. Velis, R. Weber, E. Iacovidou, P. Purnell, (2018)An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. J. Hazard Mater. 344, 179–199.

[143] Hopewell,J., Dvorak, R., and Kosior,E., (2009), Plastics recycling: challenges and opportunities. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873020/.

[144] ZWE case study on Madeira and the Azores.

[145] Nordic Council report; ZWE (2017): "Deliver or pay", or how waste incineration causes recycling to slow down.

[146] GAIA (2013): Waste Incinerators: Bad News for Recycling and Waste Reduction.

mechanical recycling, as they can be re-melted and reprocessed into new products with relative ease.

238. Physical/Mechanical recycling can be divided into direct regeneration and melt regeneration. Direct recycling of waste plastics refers to the direct plasticization or post crushing plasticization of waste plastics, that is to say, the method of making recycled plastics products after corresponding pretreatment, crushing and plasticization, and then forming and processing. Melt regeneration is a method of re-plasticizing waste plastics after hot melting, including simple regeneration and composite regeneration.

239. The simplest processes of physical/mechanical recycling involve sorting, cleaning, granulate-shredding, drying, melting, extrusion and pelletizing. Table 12 presents basic operations of mechanical recycling of shorted plastic wastes.

Table 10: Mechanical recycling operations (not necessarily sequential). Partly adopted from: DG JRC, 2014 Error! Bookmark not defined.

Process	Description
Sorting	Sorting methods are used to classify waste plastics to facilitate the continued processing. The main separation methods are manual separation method、induction sorting、overband magnet、eddy current separator、automatic sensor sorting of materials、float-sink separation、hydrocyclons， and so on.
cleaning	Use manual or machine cleaning methods to remove various oil stains, dust and garbage on the surface of waste plastic and so on.
granulate-shreddingError! Bookmark not defined.	Plastics are chopped into small flakes, allowing the separation of materials (e.g. metals, glass, paper) and plastic types (e.g., PET bottles from PP lids).
drying	Dry the plastic waste after cleaning.
melting	Heating and melting waste plastics into raw materials or products, including single-type waste plastics recycling and composite waste plastics recycling.
extrusionError! Bookmark not defined.	The flakes /pellets/agglomerates are fed into an extruder where they are heated to melting state and forced through, converting into a continuous polymer product (strand).
pelletizingError! Bookmark not defined.	The strands are cooled by water and cut into pellets, which may be used for new polymer products manufacturing.

[physical recycling flow chart will be added]

240. Some examples of mechanical recycling steps of post-consumer plastic waste are the followings.[147]

(a) Collection and sorting of PET bottles → grinding → washing →separating →drying → processing into PET bottles, polyester fibres, sheets or containers;

(b) Collection of PE-LD films used in agriculture and industrial packaging →pre-washing → grinding → washing →separating → drying → melt-filtration/re-granulation →

[147] Dataran Sunway, Kota Damansaral, (2011), A Study on Plastic Management in Peninsular Malaysia - Final Report.

processing into refuse bags;

(c) Collection of PVC pipes →grinding → washing → separating →drying → reprocessing into similar or other applications;

(d) Collecting and sorting of EPS fish boxes → washing and drying → grinding → regranulation and melt filtration → reprocessing into PS or EPS pellets or ready product.

241. The efficiency of the mechanical recycling varies based on input material characteristic and technology applied.

242. Main environmental impacts from mechanical recycling process of plastic wastes are:[148]

(a) Air emissions in the form of dust;

(b) Wastewater emissions from the washing of plastics flakes;

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

(d) Electricity consumption.

(i) Sorting

243. Waste plastics are often mixed with other impurities and different types of plastics, this may not only cause difficulty in recycling waste plastics, but may also greatly affect the quality of the products produced.

244. Plastic wastes should be separated from non-plastic wastes (such as metals, rubber, sand, fabrics) and, where appropriate and feasible, sorted into single polymer type.

245. Waste plastic sorting methods can be divided into manual and mechanical sorting.

a. Manual sorting

246. Manual sorting operations may be a pre-sorting stage before mechanical sorting. The objective is generally to remove unwanted or contaminated input materials and improve the efficiency of 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 the technical specifications of the market.

247. Manual sorting is suitable when plastic components are present in large amounts but it is a labour-intensive process and involves identification by shape, color, appearance, trademark of the plastic that distinguishes it for visual identification by the operators.[149]

248. Manual separation of plastic waste into single plastic material streams may requires experience, unless the plastic components are marked clearly with the plastic type.

249. Working conditions for workers involved in hand sorting require specific consideration.

[text to be added on guidance on how to undertake manual sorting in the safest, most environmentally sound way]

b. Mechanical sorting

i. Sorting technologies for removal of small/light/2D plastic

250. Screen separators, air classifiers and ballistic separators for the removal of small, light, 2D pieces such as film and paper and removal of heavy pieces such as glass and stone. Table 10 below provides an overview of these sorting technologies.

Table 11: Overview of sorting technologies for removal of small/light/2D plastic pieces. Adopted from ISWA , 2017[150]

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[148] Data gathering and impact assessment for a review and possible widening of the scope of the IPPC Directive in relation to waste treatment activities - Final Report, (2006).

[149] 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. Available at: https://www.researchgate.net/publication/305503715_Sorting_of_plastic_waste_for_effective_recycling.

[150] ISWA. (2017). Waste sorting plants Extracting value from waste. An introduction.

Screen separators	Trommel screen	An angled rotating cylinder with holes that allow waste 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 while transporting larger waste to the end.
Air separators	Zigzag air classifier	Waste is dropped through an upward air current in a zig-zag shaped flue. Light waste is blown to the top, while heavier waste falls to the bottom.
	Rotary air classifier	A trommel screen separator with an air current that captures the lightweight fraction.
	Cross-current air classifier	Waste is 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 waste directly from the conveyor belt.
Ballistic Separator		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		Waste is accelerated onto a rotating drum with spikes. These hook plastic film and let other waste drop.

ii. Induction sorting

251. This sorting technique is an electrostatic or triboelectric separation process which recovers metallic components, e.g. stainless steel and composite materials, which cannot be recovered using magnetic separation and non-ferrous metal sorting processes.

iii. Overband magnet (removal of ferrous metals)

252. Overband magnets are used to either lift ferrous metal from the waste or hold ferrous metal to the conveyor while other waste is allowed to drop.

iv. Eddy current separators (removal of aluminum)

253. Eddy current separators are used to push non-ferrous metals with magnets into separate collection points, with non-metallic waste falling into another.

v. Automatic sensor sorting of materials

254. NIR (Near infrared), VIS (Visual spectrometry), XRF (X-ray Flouresence), XRT (X-ray Transmission), are used for 2D items like paper and cardboard to be removed from 3D items e.g., containers. Table 11 provides an overview of sensor sorting technologies.

Table 12: Overview of sensor sorting technologies Adopted form ISWA, 2017[151]

Near infrared -NIR	Used to differentiate between plastic types (PET, HDPE, PVC, PP and PS)
Visual spectrometry-VIS	Used to identify materials based on colour
X-ray Flouresence	Used to differentiate between metals / alloys (for example, copper from steel)

[151] Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 364(1526), 2115–2126. doi:10.1098/rstb.2008.0311.

X-ray Transmission-XRT	Identifies materials based on atomic density – for example, halogens and organic components

255. AI-equipped robots that identify specific products using cameras and identifying products against an internal database of products by shape, size, color, and texture are currently available.

vi. Float-sink separation

256. This method is based on density differences of plastics. In this technique, plastics that has to be separated are placed in fluid which have density in between the materials making it possible for less dense material to float and heavier to sink. Water is commonly used for plastics with higher specific gravity.[152]

257. Float-sink separation in water can effectively separate polyolefins (PP, HDPE, L/LLDPE) from PVC, PET and PS, salinity sink float sorting for PS and ABS. 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 . Plastics containing BFR have a higher density than plastics without BFR. This technology can be used to treat WEEE and ELV plastics, as the polyolefin and styrenics fraction obtained are almost free of POP. BFRs (minor impurities in the ppm range can persist, but the vast majority of BFRs should end up more dense residuals.

vii. Hydrocyclons

258. This technique is based on the principle of centrifugal acceleration to separate plastic mixtures**Error! Bookmark not defined.**. It has no moving parts. The hydrocyclons consist of a conic and linked cylindrical body, in which there is a tangential entrance for the feeding suspension. A hydrcyclons transfer fluid pressure energy into rotational fluid motion. This rotational motion causes relative movement of materials suspended in the fluid thus permitting separation of materials from one another. The hydrocyclon device has a very high throughout rate, but it produces highly accurate density separation if plastic size is small (<6mm nominal size) and have approximately same shape. A similar sorting process for shredded plastics is centrifugal sorting. A cylindrical water- filled centrifuge is used for this purpose. The technique can selectively separate, wash and dewaste plastic flakes from a mixture of polymer waste materials.[153]

259. Although automatic technology to separate small plastic components exists, it might not be economically viable to separate them for mechanical recycling. In such as case small plastics can be bulked up and used for hydrogen generation or for energy recovery.

(ii) Cleaning

260. Waste plastics are often contaminated with dirt, dust and other wastes in different degrees. Effective cleaning of waste plastics can reduce impurities entering the granulator, reduce the number of waste filter screen and reduce production costs.

261. There are two cleaning methods: manual cleaning and mechanical cleaning. Cleaning equipment can be divided into vertical and horizontal types.

[Pictures will be added]

262. A circulating water system can be used for cleaning plastic waste, fresh water should only be used to supplement the system. Phosphorus free cleaning agents or other green cleaning agents are preferable.

263. The cleaning wastewater should be collected and then classification or centralized processing, and finally treated it cascaded or recycled.

(iii) Granulate-shredding

264. Shredding is the basic link and necessary process of plastic recycling. Crushing methods for waste plastic can be divided into dry and wet methods, while dry method is main crushing method..

[152] Wienaah MM.2007. Sustainable plastic waste management – A case of Accra, Ghana.

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

265. When using a dry method to crush waste plastics, dust prevention and noise reduction equipment is recommended; when using a wet method to crush waste plastics, the use of a filter screen can prevent small particles from entering the waste water.

266. Regardless of which crushing method is used it is advisable to acquire efficient, energy-saving technology, equipped with effective safety protection measures.

(iv) Drying

267. Commonly used waste plastics drying technologies include centrifugal dehydration, blast drying, fluidized bed drying. Enterprises should consider low energy consumption drying equipment to reduce production costs, energy conservation and emissions reduction.

268. The waste gas produced by drying often has a smell, which needs to be collected into the waste gas treatment facilities for treatment.

(v) Melting

269. Waste plastic melting technology is the process of heating and melting waste plastic into raw materials or products.

270. Encourage the use of wire mesh filter granulators to reduce waste filter production. Abandoned filters and molten residues should be collected and processed.

(vi) Extrusion

271. Melt extrusion molding refers to the process of heating and melting thermoplastic polymer materials into filaments, which are deposited on the molding surface after being sprayed by a three-dimensional nozzle.

(vii) Pelletizing

272. Pelletizing refers to the production behavior of processing into granules.

273. Waste plastics are different from new resins in performance because they have experienced the thermal history and shearing history of the molding process, and have experienced the effects of heat, oxygen, light, climate and various media during use. Therefore, the mechanical properties of the recycled materials, including tensile strength and impact properties, are lower than those of the original resin, cracks cause changes in the surface structure, and the appearance quality is not as good as before.

274. For some materials that are easy to absorb moisture, such as PA, PET, etc., during processing, moisture will cause degradation, reduce the relative molecular mass, reduce the melt viscosity, and reduce the physical properties. Before processing, the water in the waste plastics should be removed and fully dried to ensure the quality of the recycled materials.

275. Plastic additives such as plasticizers, antioxidants, etc. escape during the hot-melting process of waste plastics, which will produce toxic and harmful exhaust gases such as hydrocarbons and benzene with an irritating odor. Thus, granulated exhaust gas is suggested to be collected and processed in a centralized manner. Enterprises are encouraged to establish a vacuum-tight exhaust gas collection system.

(viii) Modification

276. Chemical modification is the process by which the properties of the material are changed by means of chemical crosslinking, grafting, and the like. The process and characteristics of the process are characterized in that a plurality of component materials are physically blended and modified while being physically blended and modified in a specific screw extruder, and further strengthened after the modification of the two components. Blend and then pelletize or form directly at a specific temperature. This is a comprehensive system integrating grafting, cross-linking and blending. This technical method can shorten the time and production cycle of the improvement process, produce continuous production, and obtain more effective modification effect.

277. Physical modification is mainly to improve the mechanical properties of recycled products by mechanical blending of recycled plastics with other polymers or additives, such as blending modification of toughening, reinforcement, blending and composite active ion filling.

278. Recycled PVC plastic companies should use environmentally friendly additives such as calcium / zinc compound stabilizers to reduce the use of lead salt stabilizers.

279. Encourage the use of low-toxic, harmless modifiers, plasticizers, phase solvents and other additives for modification. and prohibit the use of modifiers prohibited by the state.

(c) Chemical recycling

280. Chemical recycling is defined as a process in which polymers are chemically separated from one another and other wastes, depolymerized to oligomers and/or monomers, or converted into base (petro-like) chemicals that can be in several fractions and used within the petrochemical industries. Certain fractions are best suited for the creation of new monomers, others as fuel, and others could potentially give rise to lubricants. The fraction that is used as fuel should not be considered recycling. Chemical recycling may be a viable option for those waste streams where mechanical recycling is difficult due to contamination or where recycling would require costly additional separation steps.[154]

281. Polymers obtained from chemical recycling can be used within the conventional plastics industry, oligomers/monomers would need to be polymerized to polymer before being reintroduced into the plastics industry, base (petro-like) chemical fractions can be either used to produce monomers, other chemical substances (e.g. lubricants), or as a liquid fuel. Chemical recycling can be seen as a potentially complementary technology to mechanical recycling in the sense that it could potentially treat difficult to recycle plastics waste.

282. Although chemical recycling is an immature set of technologies that has nevertheless attracted considerable attention and investment. While a number of different methods have been shown to be technically feasible at the laboratory or pilot scale, technical and economic challenges remain to widespread deployment. These may be addressed through widespread build out of capacity, but expert opinion indicates that commercial maturity remains at least ten years away.

283. Common chemical recovery can be divided into thermal decomposition recovery, chemical decomposition recovery and so on.

(i) Pyrolysis

284. Pyrolysis is the thermochemical decomposition of organic material at high temperature and in the absence of oxygen or inert gases atmosphere.[155] The output of the process are base (petro-like) chemicals that can be in several fractions and used within the petrochemical industries. Certain fractions are best suited for the creation of new monomers, others as fuel, and others could potentially give rise to lubricants.

285. Waste plastic pyrolysis is regarded as the main route for the production of fuels and chemicals from waste plastics. In fact, different plastic pyrolysis processes aimed at the selective production of waxes, light olefins and monomers have been developed.[156]

286. A good raw material for the pyrolysis process is basically any material, which includes organic carbon. This is a big advantage of pyrolysis compared with the conventional biological waste management methods like composting and anaerobic digestion, because it does not require the use of complex waste separation at easy bio decomposable (biomass, food scraps, wood) harder bio decomposable (paper, natural fibres) and non-decomposable, artificial (e.g. plastics, artificial textiles, tires).

287. Pyrolysis is currently gaining attention for its flexibility in generating a combination of solid, liquid and gaseous products in different proportions just by the variation of operating parameters such as temperature or heating rate. It can also transform materials of low-energy density into bio-fuels of high-energy density and recover higher value chemicals.[157,158]

[154] Tukker, A., Simons, L., Wiegersma, S. (1999). Chemical Recycling of Plastics Waste (PVC and other resins). TNO. European Commission.

[155] Dina, Czajczyńska, Theodora, et al. Potentials of pyrolysis processes in the waste management sector[J]. Energy Procedia, 2017.

[156] Lopez G , Artetxe M , Amutio M , et al. Recent advances in the gasification of waste plastics. A critical overview[J]. Renewable & Sustainable Energy Reviews, 2018, 82:576-596.

[157] Chowdhury R, Sarkar A. Reaction kinetics and product distribution of slow pyrolysis of Indian textile wastes. Int J Chem React Eng 2012;10. doi:10.1515/1542-6580.2662.

[158] Biswal B, Kumar S, Singh RK. Production of Hydrocarbon Liquid by Thermal Pyrolysis of Paper Cup Waste. J Waste Manag 2013;2013:1–7. doi:10.1155/2013/731858.

288. Different types of pyrolysis have been developed: fast, catalytic fast, intermediate, slow, vacuum. One of the great advantages of this process is that many types of raw material can be used, including industrial and domestic residues. The fractions of MSW subjected to pyrolysis mainly include food waste, paper, cloth, plastics, and yard waste. It is then easy to understand the high variability of conditions and consequently of residues obtainable.

289. Pyrolysis is suitable for polyolefins – polyethylene (PE) and polypropylene (PP) – as they are simple hydrocarbons. It produces a range of hydrocarbon products, some of which can be used as a precursor to new chemical products, including polymers.

290. Depending on the feedstock for pyrolysis process, conditions and the type of reactor used, the yields and the composition of pyrolytic products can be significantly different. Pyrolysis of plastics containing POPs or POPs precursers has been demonstrated to generate UPOPs in emissions and residues. Dioxins emissions controls add considerable expense to this capital and energy intensive process.[159] Accordingly, other polymers especially halogenated polymers or plastics containing halogenated additives might not be best suited for the introduction into this process. Therefore, sorting steps are essential prior to introduction of material into this process.

291. According to the decomposition products, pyrolysis can be divided into three processes: oil method, vaporization method and carbonization method.

a. Oiling

292. The oiling process mainly includes four methods: tank method, tube furnace method, fluidized bed method and catalytic method. The oiling method requires that all waste plastics are used as raw materials, and no other plastic impurities can be mixed. The thermal decomposition temperature is low, about 450 ~ 500 ℃, and the main recovery products are oils. The waste plastics suitable for treatment by the oiling method mainly include PE, PP, PS, PMMA, etc., and are not suitable for PVC, PA and other plastics.

b. Gasification

293. Gasification of waste plastics leads to the production of a stream made up of mainly H_2, CO, CO_2, CH_4 and N_2. Thus, the interest of gasification processes lies in the feasibility of producing energy, energy carries (such as H_2) and chemicals from the syngas produced (fuels, DME, methanol and so on).[160]

294. Gasification has the greater flexibility to jointly valorize plastics of different composition or mixtures or plastics mixed with other feedstocks.

295. The composition, and therefore applications, of the gas produced depends on the gasifying agent used. Thus, air gasification of waste plastics leads to a syngas with an average heating value in the 6–8 MJm−3 range[161,162] with its main interest being energy production.

296. Steam pyrolysis (500◦C) of high density polyethylene (HDPE) in a conical spouted bed reactor followedby a steam reforming (700◦C) in a fixed bed reactor (Ni commercial catalyst) has been carried out forobtaining a syngas stream rich in H_2.[163]

297. The main challenge of waste plastics gasification is the high tar content in the gas product, i.e., usually higher than those reported in biomass gasification.[164] Thus, a very

[159] Yang X1, Sun L, Xiang J, Hu S, Su S. (2013). Pyrolysis and dehalogenation of plastics from waste electrical and electronic equipment (WEEE): a review. Waste Manag. 2013 Feb;33(2):462-73.

[160] Sansaniwal SK, Pal K, Rosen MA, Tyagi SK. Recent advances in the development of biomass gasification technology: a comprehensive review. Renew Sustain Energy Rev 2017;72:363–84.

[161] Sancho JA, Aznar MP, Toledo JM. Catalytic air gasification of plastic waste (polypropylene) in fluidized bed. Part I: use of in-gasifier bed additives. Ind Eng Chem Res 2008;47:1005–10.

[162] Arena U, Di Gregorio F. Energy generation by air gasification of two industrial plastic wastes ina pilot scale fluidized bed reactor. Energy 2014;68:735–43.

[163] Erkiaga A , Lopez G , Barbarias I , et al. HDPE pyrolysis-steam reforming in a tandem spouted bed-fixed bed reactor for H-2 production[J]. Journal of Analytical & Applied Pyrolysis, 2015, 116(NOV.):34-41.

[164] Pinto F, André R, Miranda M, Neves D, Varela F, Santos J. Effect of gasification agent on co-gasification of rice production wastes mixtures. Fuel2016;180:407–16.

efficient gas cleaning system is needed to meet the requirements for applying the syngas to chemical production.[165,166]

(text for environmental impacts to be added)

(ii) Chemical depolymerization

298. Another chemical recycling methods for plastic wastes is chemical depolymerization. Chemical depolymerisation is the breaking down of a polymer into either monomers or intermediates using catalysts or solvents which could be:

(a) Water (hydrolysis);

(b) Monoethylene glycol (glycolysis);

(c) Methanol (methanolysis);

(d) Amino groups (aminolysis);

(e) Catalytic depolymerization using microwaves.

299. Chemical depolymerization could be a solution for specific polymers that contain specific chemical bonds (e.g., PET, PUR, PC) and results in mono- and/or oligomers that can be converted back into polymers.

300. The products of chemical depolymerization are relatively simple and easy to control, and the production equipment is relatively simple. The waste plastics provided by chemical depolymerization method are relatively clean and single, and the mixed waste plastics are not applicable. For most carbon chain and heterochain plastics with stable structure, such as polyolefin, chemical depolymerization can not be carried out; for chemical depolymerization, polymers with water or alcohol sensitive groups, such as polyurethane and thermoplastic polyester, in addition to polyamide, polymethylmethacrylate (PMMA), POM, etc.

301. Alcoholysis is a method to depolymerize some polymers and recycle raw materials by using hydroxyl groups of alcohols. This method has been applied to PU, PET and other plastics. In the alcoholysis of PET, there are methanol decomposition method with methanol as the solvent, glycogen alcoholysis with glycol as the solvent and hydrogenolysis with acid or alkaline aqueous solution, etc.

302. A relatively pure feedstock, such as washed PP from margarine tubs and other packaging, is dissolved in a suitable solvent. Any colourants, additives and non-target materials are removed, and the resulting polymer can be re-formed. This differs from pyrolysis because the polymer is not broken down, making its recovery for use in new products easier.

303. It is being developed primarily for polyethylene terephthalate (PET). Similar to recycling using solvents, the process removes additives and colourants while contamination is filtered out. The monomers are polymerised to produce virgin-quality PET. [Technology of PS, PP and PE will be added]

304. For the thermoset PUR a number of technologies are also emerging. For example, an acidolysis process has been developed to produce a polyol, a major raw material in PUR formulation, that can be upscaled for the recycling of PUR foams.[167]

305. Challenges with chemical depolymerisation include the need to prepare the feedstock to remove as much contamination as possible.

306. A major benefit is that it can be used to create food-grade recycled rPP – for example, margarine tubs can be turned back into new ones. It can also be used to recover PE or PP from multi-layer, non-recyclable packaging such as single-use sachet products, the collection and recycling of which would help to reduce pollution issues such as plastics entering the oceans.

[165] Guan G, Kaewpanha M, Hao X, Abudula A. Catalytic steam reforming of biomass tar: prospects and challenges. Renew Sustain Energy Rev 2016;58:450–61.

[166] Shahbaz M, yusup S, Inayat A, Patrick DO, Ammar M. The influence of catalysts in biomass steam gasification and catalytic potential of coal bottom ash in biomass steam gasification: a review. Renew Sustain Energy Rev 2017;73:468–76.

[167] http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-72e45eef-3b24-4ee6-8035-38ede26d4308.

307. Chemical depolymerization has its challenges: solvents can be expensive and solvent recovery is key. The more non-target material present, the higher the cost of recycling owing to potential solvent loss. Feedstocks require high levels of sorting and purity before dissolution and the process is technically challenging to develop and operate. In addition, challenges with chemical depolymerisation include the need to prepare the feedstock to remove as much contamination as possible.

(text for environmental impacts to be added)

(d) Main factors affecting recycling of plastic waste

308. A number of factors impede the development of the plastic waste recycling sector, both in developed and developing countries. Table 13 shows the main blocking factors affecting the collection and recycling of each source of plastic waste in Western Europe.

Table 13: Difficulty for Recycling on a Likert scale (1 = easiest, 5 = hardest)

Blocking Factor	MSW	Pre-consumer	Distribution	Agriculture	ELV	WEEE	B&D
Geographical Dispersion of Waste	5	2	2	3	1	4	2
Difficulty in Identifying the Polymers	4	1	1	1	3	3	2
Difficulty in Dismantling	1	1	1	1	4	4	2
Use of Composite or Multi Plastics material	5	2	1	1	4	3	2
Use of Composite or Multi Plastics material	5	1	1	3	5	5	3
Contamination with other Material	2	1	2	1	5	5	3- 5
Contamination with Substances	5	2	2	3	1	4	2

309. Limited recyclability of plastic wastes due to the deterioration of their properties in each recycling phase is a disadvantage of the mechanical recycling of plastic waste. That is why recycled plastic is often mixed with virgin plastic in order to increase the mixtures value. In addition, the heterogeneity of certain plastic waste (e.g., municipal waste) is an obstacle (but not a deterrent) on recovering large homogenous amounts of targeted plastic for efficient mechanical recycling.

310. The identification of polymers can be done in advanced sorting installations, however the use of multilayer material and or the combination of several materials in a single article (e.g., PET bottles with full PVC sleeves) are still hampering the identification and proper sorting. Contamination by other materials can be reduced through separate collection systems, however residues of other material (e.g. food residue) may remain an issue. Most plastics waste in MSW is packaging or other plastics waste with short life cycles. The presence of hazardous substances is normally not an issue however, the presence of pigments, inks, glues, etc. may affect the quality of recyclate produced from this waste stream. When recyclate is destined for food contact applications, contamination needs to be addressed.

311. Pre-Consumer waste (e.g., production cut offs) are generated across the plastics industry sites. As there is a general tendency to minimize such waste by companies themselves (e.g., by recycling internally), batches are typically of small quantities, of known composition, and are less frequently contaminated with other materials. Some companies produce difficult to recycle materials (e.g., glass fiber reinforced PP), although this is not the majority of the market. Contamination with legacy substances should not be expected.

312. There is some geographical dispersion of distribution waste, however the material is typically readily identifiable and suffering from minimal contamination with other material. The presence of legacy substances should not be of great concern, however reusable plastics distribution waste with longer life cycles (e.g. crates and pallets) can contain heavy metal pigments that can be restricted in some parties in certain applications.

313. Agricultural plastic waste is typically geographically distriuted as all agricultural activity. Identification of polymers is relatively easy (mainly LDPE) and the use of multi plastics material is low, however significant mineral contamination is to be expected. Being of short life cycles, the presence of legacy substances is likely to be minimal to nonexistent.

314. Collection systems for end of life vehicles (ELV) in developing countries ensure that plastics waste fractions are generated at specific location where limited dismantling and shredding take place. Identification of polymers is relatively difficult due to the high use of black plastics making NIR sorting difficult. However, other technologies exist and are employed in the treatment of this plastics fraction. Fully dismantling of ELV will never be an economically feasible option and the shredded material is likely to contain other material impurities. The automotive industry tends to be driven by light weighting and has been replacing many metallic parts with plastics. Such metal substituting plastics have high specifications that can sometimes not be obtained without the use of composite material (e.g. carbon fiber reinforced plastics). In plastics parts that are in contact with heat, flame retardants are normally used. Given the long-life cycle of vehicles, these parts are likely to contain POP BFRs and recycling operations should take this into account.

315. Waste Electrical and Electronic Equipment (WEEE) is geographically highly dispersed and in the absence of specific collection systems will likely end up in either waste collected from municipal drop off points (e.g. large appliances) or MSW. The creation of specific collection systems, potentially under the supervision of an EPR scheme, are highly recommended to ensure environmentally sound management of such waste. When such a system is in place limited dismantling and subsequent shredding will likely take place at few facilities where a plastics fraction is then generated. Similar considerations as in ELV apply to the identification of polymers. The use of composite material is occurring, although not to an extend as in ELV. The plastics fraction is likely to be contaminated with other materials and having a medium-term life cycle the presence of POP BFRs is of concern. The plastics fraction should be treated in such a manner that creates recyclate that is almost free of these substances.

316. Construction and demolition (C&D) waste is generated during building and demolition operations. In specific applications specific polymers are frequently used which can make identification easier (e.g. a pipe is either HDPE or PVC and foam boards can be recognized by colour, PS = white PUR = yellowish). The use of composite material is not widespread in this sector. Waste materials are likely to have a certain degree of mineral contamination and may contain other materials (e.g. rubbers in PVC window profiles), however this is easily addressed. PS foam boards are likely to contain HBCDD and need to be destroyed unless a new technology is developed able to separate this additive from the material. PVC components may contain lead or cadmium stabilizers, the use of which may have been regulated when the material was installed; although this will depend on local legislation.

[Issues such as policies, markets, attributes of the plastics industry, price balance between plastic raw materials and recycled materials will be added.]

(e) Specific aspects on recycling of main types of plastic waste

(i) Recycling of waste polyethylene (PE)

317. Polyethylene (PE) is a thermoplastic, elastic polymer. It is used in plastic containers, bottles, bags and plastic toys. In addition, it can be used for the production of plastic cement. PE belongs to the polyolefin family of polymers. The types of PE, depending on its density and branching, are: Branched Versions (Low-density polyethylene (LDPE) and Linear low-

density polyethylene (LLDPE)), Linear Versions (High-density polyethylene (HDPE) and Ultra-high-molecular-weight polyethylene (UHMWPE) and Cross-linked polyethylene (PEX or XLPE). The most common of them are LDPE and HDPE (Omnexus, 2019).[168]

318. LDPE is difficult to be recycled. However, many recycling programs are beginning to accept LDPE plastics because the market for recycled LDPE is growing. The recycling process includes melting the plastic to eliminate contaminants. After putting the LDPE under heat, the material is fashioned into thin plastic sheets which are sold to manufacturers. Good quality LDPE is found in household items like plastic wrap, grocery bags, frozen food containers and bottles. Recycled LDPE can be made into garbage cans, paneling, furniture, flooring and bubble wrap.

319. Most film products are LDPE, as such it is collected from MSW, it is a by product of PET bottle recycling (sleeves), is collected extensively from distribution systems, and collected from agriculture. Bales of film provide a yield of 80% to almost 100% depending on origin with 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).

320. HDPE is normally treated through mechanical recycling. At first, the plastic is sorted and cleaned in order for any unwanted debris to be removed. Then it needs to be homogenised so that only HDPE will be processed. In case there are other plastic polymers in the batch, it can ruin the recycled end-product. HDPE can be separated by Near Infrared Radiation (NIR) techniques. However, if the plastic is too dark, which means it absorbs the infrared waves, this technique cannot be used. HDPE is then shredded and melted down to further refine the polymer. In the end, the plastic is cooled into pellets which can be used in manufacturing. Recycled HDPE is in very high demand for production into pens, plastic lumber, plastic fencing, picnic tables and bottles.

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

322. HDPE obtained from ELV and WEEE is often sorted by density separation to obtain a polyolefin stream (PE+PP). Further separation technology exists (e.g. electrostatic interaction), however these polymers have a limited compatibility with one another and can be molten into new products together. The compatibility can be enhanced through the use of compatibilizing additives. Whether an additional separation step is carried out or not will depend on the balance between the cost of separation per ton and the premium the customer is willing to pay for the separated material vs the customer that purchases the mixed fraction."

323. PE foam can be divided into two types, cross-linked and non-cross-linked. Cross-linked foam accounts for about 50% of the PE foam market and grows at a rate of 25% per year. Cross-linked foamed PE plastics are widely used in packaging and thermal insulation materials in industry and construction.

324. Pyrolysis of waste polyethylene is divided into gas production, oil production and wax production technology, which is to thermally decompose or catalytically crack polyethylene to make small molecule compounds, and then use this way to chemically process polyethylene into energy, chemical raw materials, etc.

325. PE is usually mixed with PP and PVC. The three varieties of PE, namely HDPE, LDPE and LLDPE, are also easy to mix together. PE has a certain compatibility with PP, but has poor compatibility with PVC, so even if the amount of PVC is small, it must be separated.

326. The presence of a small amount of PP in PE will not affect the performance of the recycled material, but if the amount of PP is large, EPDM can be considered as a compatibilizer for blending.

327. Both LDPE and LLDPE have similar properties and are difficult to separate, but they have good compatibility and can be blended without the addition of a compatibilizer. Of

[168] Omnexus, the material selection platform, Polyethylene (PE), 2019,
Retrieved from https://omnexus.specialchem.com/selection-guide/polyethylene-plastic, 12.11.2019.

course, the ratio of the two is different, and the performance of the recycled material will also be different.

328. HDPE and LDPE, HDPE and LLDPE can also be blended in a certain proportion, the specific proportion depends on the performance of the recycled material, such as blending a certain proportion of LDPE or LLDPE in HDPE, can improve stress resistance, crack resistance and warpage resistance.

(ii) Recycling of waste polypropylene (PP)

329. Polypropylene (PP) is a thermoplastic polymer used in products such as food containers, packaging, toys, furniture, cars, E&E devices and textiles. It is characterized by being durable, transparent and resistant to chemical stress and it can sometimes contain dyes, antioxidants and, in some cases, flame retardants. PP is one of the most popular plastic packaging materials in the world.

330. PP obtained from MSW (e.g. margarine trays), bulky waste (e.g. garden furniture), distribution (e.g. crates and pallets), and B&C can be sorted into relatively homogeneous streams.

331. Regarding its mechanical recycling process, the last two steps, reprocessing by melting and producing new products from recycled PP, are critical. In the reprocessing phase, collected PP products are fed into an extruder where it is melted at 4,640 °F (2,400 °C) and cut into granules.

332. The co-cracking of waste PP materials and other materials can overcome the shortcomings of low product yield due to poor thermal conductivity and uneven reaction temperature when cracking a single plastic. In addition, physical or chemical methods can also be used to modify the waste PP plastic to improve its mechanical properties, so as to meet the requirements of reuse.

333. Recycled PP is generally mixed with virgin PP at up to 50% for the production of new products such as clothes or playground equipment. Also, some of the applications of recycled PP are compost bins and kerbside recycling crates.

(iii) Recycling of waste polyvinyl chloride (PVC)

334. Polyvinyl chloride (PVC) is one of the most commonly used thermoplastic polymers in the world. In its natural state it is a rigid material with extreme durability and cost performance. It can be made flexible through the addition of plasticizers. The majority of PVC is used in building and construction applications such as: window profiles, pipes and fittings, vinyl flooring, water proofing membranes, wall cladding, and cable sheeting. Other applications where PVC can be used are: packaging, blister packs, blood bag systems, shoe soles, and watch straps.

335. PVC is being recycled by either one of the two following ways: Mechanical recycling, which involves mechanically treating the waste (e.g. grinding) to reduce it into smaller particles. The resulting granules can be melted and remolded into different products, usually the same product from which it came. And feedstock recycling, which includes chemical processes such as pyrolysis, hydrolysis and heating. The resulting products, that aresodium chloride, calcium chloride, hydrocarbon products and heavy metals to name a few, are used to produce new PVCas feed for other manufacturing processes.

336. Recycled PVC can be found in packaging for food, textile, medical materials and drink bottles. PVC can also be recycled in flooring, film and sheets, cables, speed bumps, packaging, binders, mud flaps and mats.

(iv) Recycling of waste polystyrene (PS)

337. Polystyrene (PS) is a common thermoplastic that is used in a variety of plastics products. High Impact Polystyrene (HIPS) and General-Purpose Polystyrene (GPPS) can be found in electrical and electronic equipment, vehicles, food packaging (e.g. yoghurt trays), and laboratory plastics. Foamed PS, also called expandable PS (EPS), is used in building and construction to produce insulation boards (Styrofoam).

338. Environmental and health concerns regarding PS include emissions of toxic chemicals and POPs during production & disposal (PAHs). PS is a polymer of styrene, a known

carcinogen, systemic toxicant, and skin and eye irritant (corrosive). It has also leaches styrene into food and beverages when used as a food or beverage container.

339. Recycling of PS can be done by mechanical, chemical, and thermal methods. High impact polystyrene is a promising material for mechanical recycling since its properties are not extremely affected even after multiple processing of up to nine cycles. PS's recycling rate is low due to the difficulty in removing food residues and odours from used polystyrene.

340. Disposable cutlery consists of recycled PS. Plastic foam is troublesome for most material recovery facilities A big challenge in recycling polystyrene is contamination. If oily molecules, water, and other contaminants make it into recycled materials, the substances can disrupt and weaken the polymers. Polystyrene clamshell containers and coffee cups are especially likely to be dirty, adding to the cost of processing them for recycling. Polystyrene contaminant problem can be addressed by either chemical processing or thermal treatments (i.e. energy recovery in incineration plants.[169]

(v) Recycling of waste polyethylene terephthalate (PET)

341. Polyethylene terephthalate (PET) is a clear, strong and impact resistant plastic, commonly found in packaging applications such as beverage bottles, perishable food containers, mouthwash, jars and plastic bottles. PET also is used in textiles and its materials may contain dyes and color pigments.

342. The process of recycling recycled polyester bottles to prepare fibers is generally to crush, sort, wash, melt and pellet the polyester bottles, and then slice and dry them for screw spinning. Because the processes of melt granulation and chip drying are difficult to control relative to virgin polyester, the products of bottle flake fiber are often limited to areas with relatively low requirements for dyeing and fiber uniformity.

343. PET can be recycled by thorough washing and re-melting, or by chemically breaking it down to its component materials to make new PET resin. It can be cleaved by some reagents, like water (hydrolysis), acids (acidolysis), glycols (glycolysis) or alcohols (alcoholysis). According to the reagent used, different products are obtained. Some PET is diverted for incorporation in construction materials such as cement, concrete and road pavement raising concerns that microplastics and chemicals may leach during use and demolition. Recycled PET can be found in carpets, furniture and garments.

344. PET is one of the easiest plastics to recycle and has the highest recycling rate of any common plastics. Many examples of closed loop recycle (e.g. bottle to bottle) exist. This is because it is relatively easy to upgrade the intrinsic viscosity (polymer chain length) during the recycling process to near-virgin quality using polycondensation reactions.

(vi) Recycling of waste acrylonitrile Butadiene Styrene (ABS)

345. Acrylonitrile Butadiene Styrene (ABS) is a durable copolymer thermoplastic manufactured from the polymerization of the monomers butadiene, styrene and ascrylonitrile. It is primarily used in electric and electronic equipment (e.g., computer housings, televisions and computer monitor housings) and automobile components of in vehicles.

346. In the presence of oxygen, when ABS is exposed to heat, mechanical stress, ion or ultraviolet radiation, it will produce some active intermediates, such as free radicals, hydroperoxides, ROOH, etc., and eventually lead to oxidative degradation of ABS.

347. ABS can be recycled mechanically. At present, the ABS regenerated material can be mixed with other types of waste plastic regenerated materials, and by adding various functional additives, the modified ABS material with good toughness, corrosion resistance, oil resistance, cold resistance, weatherability and anti-aging property can be produced at the present time. When recycled, ABS can be used as a mixture of virgin material to produce products of low cost with high value. Some products made from ABS plastic are cases for electrical devices, automotive bumpers and other parts, aircraft and aerospace applications, luggage cases, toys, musical instruments, protective headgear, containers, furniture etc.

[169] Lemonick, S. (2019). Chemistry may have solutions to our plastic trash problem. Available at: https://cen.acs.org/environment/pollution/Chemistry-solutions-plastic-trash-problem/96/i25.

348. Since most of the ABS used in electronic and electrical products after consumption use organic bromide as flame retardant, attention need to be raised to the content of brominated dioxane and brominated furan in the recovery process of ABS. In addition, attention also need to be given to the change of ABS performance in the recycling process. For example, after the ABS shell is broken, cleaned and dried, the melt flow index (220℃, 0.98mpa) decreases from the glass transition temperature.

349. ABS is primarily found in WEEE and ELV streams. The concentration of styrenics is slightly greater in WEEE than in ELV plastics. Similar to the treatment of PS in from these fractions NIR is not a viable technology due to the extensive use of black plastics. However, density separation can be employed to create a styrenics fraction (PS+ABS) that is almost free of POP BFRs. Further separation might not be necessary as these polymers poses some compatibility, though can be done for higher end applications using electrostatic sorting. The recyclate can sometimes be reintroduced into their original applications (e.g. vacuum cleaners) or into lower end applications (e.g. nonfood containers).

(vii) Recycling of waste Polycarbonate (PC)

350. Polycarbonate (PC) is a high-performance tough, amorphous and transparent thermoplastic polymer which has an organic functional group linked together by carbonate groups and offers a unique combination of properties. It is used as an engineering plastics thanks to its high impact strength, its high dimensional stability and its good electrical properties, amongst several others. It is commonly used for plastic lenses in eyewear, in medical devices, automotive components, protective gear, greenhouses, Digital Disks (CDs, DVDs, and Blu-ray), and exterior lighting fixtures. PC is, under certain circumstances, able to degrade to some extend to produce its monomer (e.g. Bisphenol-A).

351. PC recycling can be performed in three different ways, which are mechanical recycling, recycling via chemical methods and thermochemical recycling, also called as pyrolysis. 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 toughened by adding toughening agent.

(viii) Recycling of waste polyamide (PA)

352. Polyamides (PA) are crystalline polymers typically produced by the condensation of a diacid and a diamine. PA is used in textiles for clothing and carpets, making tyre cords - the inner structure of a vehicle tyre underneath the rubber. Another type of PA (Kevlar) is used in bulletproof vests, in composites for boat construction, in lightweight mountaineering ropes, and for lightweight skis and racquets - amongst many other things. PA can be recycled through mechanical and chemical methods. There is also a possibility for thermomechanical recycling of polyamide 6 (PA6) from fishing nets waste.

353. PA has a wide range of applications. In general, specific waste PA can be recovered by mechanical recovery and chemical recovery. The mechanical recycling of PA includes the recycling of glass fiber reinforced PA66 injection molding parts, the recycling of PA multilayer composite film Ji and the recycling of PA fishing net.

354. Like PET chemical recovery, PA chemical recovery uses mechanical recovery materials. Depolymerization requires a certain reactor, which has large investment, high cost and limited application. However, PA synthesized after chemical recovery has the same performance as the original resin and can be used as raw resin.

355. The recycled PA can be used in the making of fishing, carpets and waste from manufacturing industry. It is also used in swim wear. Additionally, nylon polyamide 12 (PA12) powders are used for 3D printing products.

(ix) Recycling of waste polyvinyl butyral (PVB)

356. Polyvinyl butyral (PVB) is a clear, colorless, amorphous thermoplastic obtained by condensation reaction of polyvinyl alcohol and butyraldehyde. The resin is known for its excellent flexibility, film-forming and good adhesion properties as well as outstanding UV resistance. PVB can be recycled mechanically and chemically. Though, the last method is not economically profitable. Recycled PVB is separated into three categories. Category 1 includes transparent PVB (98% of PVB, free of any impurity), category 2 refers to colorless PVB (2% of impurities and 96% of PVB), while category 3 represents colored PVB (70% of PVB and 4% of impurities).

357. PVB is recovered from laminated glass by mechanical peeling. The most important application of PVB film is laminated safety glass for automobile windshields. PVB films find also applications in the construction industry as laminated safety and security glass, as well as in the photovoltaic industry to improve the long-term durability of solar modules.

358. Since most PVBs have been dyed, PVB films containing color can only be discarded or used for low-level applications such as the production of shoe soles.

359. PVB diaphragm is a typical polar heat-sensitive material. The recovered PVB membranes fluctuate greatly in terms of quality stability and product weather resistance.

360. At present, there are mainly the following ways to recycle PVB membranes:

(a) PVB diaphragm is used as plastic toughening agent;

(b) Using PVB membrane as the matrix to prepare composite materials;

(c) Recycled PVB membranes are used as coatings or adhesives.

(x) Recycling of bio-based biodegradable plastics

361. Bio-based biodegradable plastic wastes could be treated with mechanical recycling, chemical recycling and composting. Treatment of bio-based plastic wastes is relatively new and the knowledge up to now is limited.

362. One of the most studied bio-based plastics is PLA. PLA is a neutral component in the recycling stream and can be effectively sorted out using available detection technologies, because PLA can be sorted from other plastics in the recycle stream at approximately 98% accuracy, using NIR detection technology. Also, chemical recycling is possible to occur. For example, PLA hydrolysis at high temperatures to obtain lactic acid (see Figure 7).

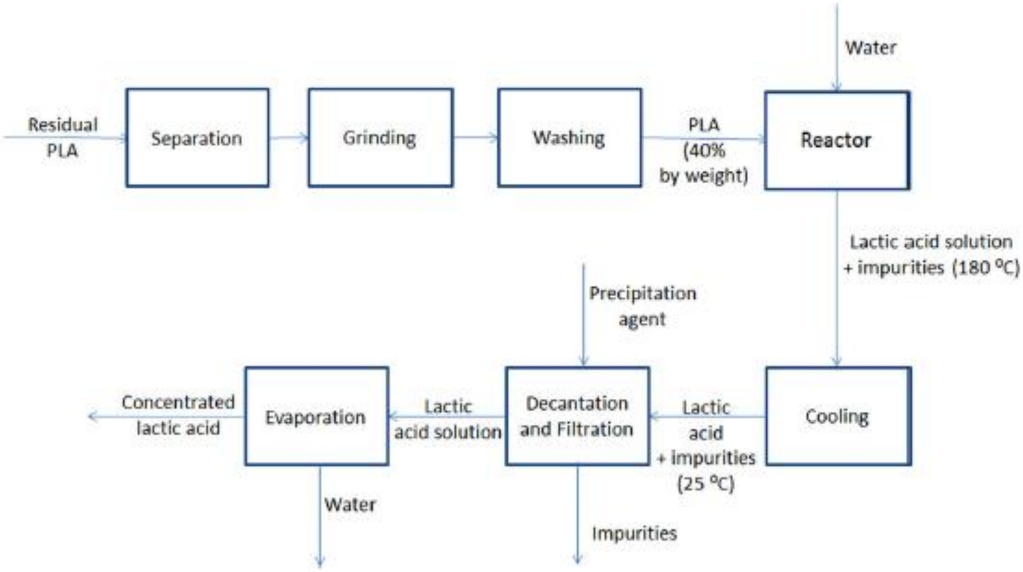

Figure 6: Hydrolysis step in PLA chemical recycling[170]

363. Mechanical recycling of bio-plastics is the most favourable technology for the industry but it still has some limitations. For example, it may be difficult to convert PLA waste into useful products, especially thermomechanical degradation during extrusion. Therefore, after each cycle the product quality is lower compared with the starting material and thus its market value decreases. On the other hand, maintaining the quality of the recyclate is vital for ensuring the feasibility of the process and the market value.

[170] Marina F. Cosate de Andrade, Patrı´cia M. S. Souza, Ota´vio Cavalett, Ana R. Morales, "Life Cycle Assessment of Poly(Lactic Acid) (PLA): Comparison Between Chemical Recycling, Mechanical Recycling and Composting" , J Polym Environ, 2016.

364. Composting is currently in use for some bio-based and biodegradable plastic applications e.g. PLA as waste collection bags.[171]

365. At present, the research and development of degradable plastics is not mature, and there are some problems in degradable plastics, such as the poor heat resistance of PLA, the poor water resistance of PBAT film, the large difference in the vertical and horizontal strength of degradable film, and the poor thermal sealing performance of degradable shopping bags. At home and abroad, modification technology is widely used to improve its degradation performance, such as filling modification and micro foaming modification technology.

2. Energy recovery from plastic wastes

366. Energy recovery is to obtain the high heat generated by its combustion and use it effectively. The energy recovery of waste plastics generally does not use pure waste plastics. Plastic wastes are incinerated with other kinds of municipal solid waste, industrial waste, etc. Waste plastics account for about 15% -20% (volume fraction), or 5% -8% (mass fraction), is the main heat provider. According to reports, generally, every ten tons of municipal solid waste is burned for 1 hour, 33 tons of steam with a pressure of 3.45MPa and a temperature of 204° C could be get (equivalent to the energy of burning 3080 cubic meters of natural gas or 1956L of fuel oil).

367. While some plastics waste can be recycled resulting in environmental benefits, a lot of plastics waste consists of small items dispersed among other waste materials. Separating and cleaning this waste for recycling may have an environmental burden higher than the profit from recycling, without taking into account the economic cost. There are residues from the recycling process, which cannot themselves be recycled.

368. If recycling or composting (for biodegradable plastics) cannot be justified or is not allowed (e.g. plastic waste which contains POPs above certain limits), then energy recovery may be the cost-effective way of retrieving the intrinsic resource value of the plastics waste. It should be noted however that if energy recovery is applied the energy that was necessary for the production of the plastics is lost. For certain types of plastics, the amount of energy needed to produce the material is in the same order of magnitude as the energy value of the plastics when incinerated.[172]

369. Most plastics are hydrocarbon polymer compounds that can burn and produce a high calorific value. (see Table 14). Even those containing halogens have an energy value similar to paper and cardboard. On the other hand, the incineration of plastics can also bring environmental pollution of combustion gases and dust. Incineration may result in generation of large quantities of flue gas cleaning residues which are heavily contaminated with POPs and must be subject to hazardous waste provisions. (see Table 14). Energy recovery is the process of utilizing waste (plastics) as substitutes of primary fossil fuel resources for the production of fuel, for energy recovery in the form of heat, steam or electricity generation (SS-ISO 15270:2009).[102]

370. The current energy recovery methods for waste plastics are:

(a) Incineration of plastic waste at a special incinerator to gain energy;

(b) Blast furnace injection of waste plastic;

(c) Cement rotary kiln injection of waste plastic;

(d) Use of waste plastic to make solid waste fuel.

371. Waste plastic as fuel has many advantages:

(a) Effectively dispose of waste plastics;

(b) The mass and volume of waste materials after incineration can be reduced by 90%;

(c) Help to eliminate toxic substances in waste plastics and reduce environmental pollution;

[171] Sebastian Spierlinga Carolin Röttgera Venkateshwaran Venkatachalama Marina Mudersbacha Christoph Herrmannb Hans-Josef Endresa (2017) Bio-based plastics – A building block for the circular economy?

[172] APME Publication. (1996). A Fuel for the Future.

(d) Especially suitable for the recycling of energy-intensive polymer products, aging and degrading plastic products and plastics containing toxic residues as energy sources.

372. Research and practice developed over the past 10 years have indicated that, under strict operating conditions, plastic wastes, even if the mixture is rich in PVC, can be incinerated safely and effectively. However, PVC is a key precursor to dioxin formation and BAT BEP implementation is required to control dioxin to levels within regulatory emission thresholds (PCDD/DF 0.1 ng ITEQ Nm^3).[173] PVC is an important source of chlorine in Municipal Solid Waste (MSW). On average in the EU 50% of the chlorine in the input of incinerators of MSW comes from PVC (range 38 – 66%). During incineration, chlorine (including the chlorine in PVC) is transformed into hydrochloric acid, which has to be neutralised to meet emission standards. As an example, the emission standard for HCL in the EU is 10 mg/Nm^3. After neutralisation a reaction residue from flue gas cleaning remains. Table 15 gives an overview of the amount per kg PVC of neutralisation agent needed and the amount of residue generated in the different flue gas cleaning systems in operation. These figures are based upon the average composition of PVC waste. Soft PVC will generate less residues than rigid PVC, due to the lower chlorine content.

Table 14: Use of neutralisation agent and production of residues due to incineration of PVC waste

Flue gas cleaning system		**Dry**		**Semi-dry**	**Wet**	**Semi wet- wet**
Neutralisation Agent (NA)		Lime	Bicar	Lime	Lime	Lime
NA kg Per kg PVC	Min	0.52	0.62	0.44	0.29	0.29
	Max	1.11	1.32	0.94	0.61	0.61
	Average	0.94	1.12	0.79	0.52	0.52
Residue kg per kg PVC	Min	0.78	0.46	0.70	0	0.54
	Max	1.65	0.97	1.48	0	1.15
	Average	1.40	0.82	1.26	0	0.98
Liquid effluent (dry material) (kg per kg PVC)		0	0	0	0.42 – 0.88	0

373. Waste collected from household is listed in Annex 2 of the Basel Convention as needing special consideration. It is untreated household waste and waste from shops and restaurants, which is burned in large 'mass-burn' facilities in Europe, US, and Japan. MSW has an energy value of 10 MJ/kg and a very low density. Its plastics content assists the incineration of wet or putrescible materials within the waste stream.

374. Refuse derived fuel (RDF) is produced by removing all the 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 plastics waste than MSW and consequently a higher energy value. It may be environmentally acceptable to transport RDF short distances from its place of manufacture to authorised authorized energy recovery plants.

375. Solid Recovered Fuel (SRF) is a fuel produced from non-hazardous waste in compliance with the European standard EN 15359. Although this standard is not an obligation, the main requirement is that a producer specifies and classifies its SRF by detailing its net calorific value, and chlorine and mercury content of the fuel. Specification includes (as mandatory) several other properties, such as the content of all heavy metals mentioned in the Industrial Emissions Directive.[174]

376. Packaging derived fuel (PDF) consists mainly of paper and plastics waste kept separate from the generality of waste and prepared in pellet form designed to give an even higher energy value.

[173] Tait, P.W., Brew, J., Che, A., Costanzo, A., Danyluk, A., Davis, M., Khalaf, A., McMahon, K., Watson, A., Rowcliff, K. and Bowles, D. (2020), The health impacts of waste incineration: a systematic review. Australian and New Zealand Journal of Public Health. doi:10.1111/1753-6405.12939.

[174] Directive 2010/75/EU of the European Parliament and the Council on industrial emissions.

377. Polymer fuel (PF) consists of plastics waste alone, either from recycling processes or separated from the general waste stream and processed to yield a fuel of specified polymer content and energy level.

378. Many constructed incinerators may not be designed to withstand the temperatures generated when such a high calorific value is used alone. The fuel should be diluted with material of lower calorific value.

379. Both PDF and PF may originate from industry, distribution or municipalities through the 'drop-off' or 'kerbside' collection systems.

Table 15: Energy values of plastic wastes, mixtures and traditional fuels

Single polymers/*fuels*	**Net calorific value (MJ/kg)**
P E-LD/PE-HD	45
PP	45
PS	41
ABS, *Oil*	40
Coal	25
PET	23
PVC	22
PDF	20
RDF MSW, *Wood*	15-17 8 -10
Mixtures (PF)	
P E-LD/PP/PE-HD (food packaging)	45
PP/ABS/PE-HD (computers)	43
P E-LD/PP/PVC (mixed packaging) PP/PE-LD/PVC (non-food packaging)	37 37
PU/PP/PVC/ABS (bumpers/fuel tanks)	33

380. In the context of the incineration of plastic wastes it is also important to consider the updated draft updated technical guidelines concerned with incineration on land (D10).8 When the incineration is with energy recovery, draft technical guidelines concerned with energy recovery (R1) is beneficial. For the disposal of incineration residues, it is also important to consider the draft updated technical guidelines on specially engineered landfill (D5) (UNEP/CHW/OEWG.11/INF/19).11

381. For consultation on ESM of plastic wastes with co-incineration in cement kiln advice Chapter IV. G of the General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (General POPs) UNEP/CHW.14/7/Add.1/Rev.1 and the technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP/CHW.10/6/Add/3/Rev.1).10

3. Final disposal of plastic wastes

382. Where there is no possibility of employing the recovery from processes listed above then plastics waste may be deposited in authorized landfills. Incineration without energy recovery is used to reduce the volume of the residues deposited in the landfill.

(a) Incineration without energy recovery

383. The main difference between incinerator or installations with energy recovery and those without energy recovery is the use of waste as a potential source of heat - through steam, or electricity by the conversion of stream.

384. The same key factors are important:

(a) The nature of the waste to be incinerated;

(b) Incineration conditions control;

(c) Flue gas cleaning.

(b) Landfill

385. Landfill is the least preferable option for the management of plastic waste since no use is made of any of the resources represented by plastics. Although it requires space, it is still the most commonly practised waste disposal method in the majority of countries. Due to the low costs of landfilling, alternative waste management options are often unattractive from the economics point of view.

386. The Basel Convention has produced technical guidelines on the establishment of specially engineered landfills used for wastes which exhibit one or more hazardous characteristics11, or other waste. These guidelines also consider the issue of existing sites which require strict control and often, remedial treatment. Only those landfills meeting the requirements of the Basel Convention guidelines should be employed.

387. Landfills have caused concern when organic materials in them are broken down by biological action to produce flammable methane gas. There have been concerns that some additives (phthalates) used in plastics could be leached out into the ground water in the landfill. Losses of plasticisers from soft PVC are widely documented in literature.[175]

388. DEHP, the most commonly used plasticiser in soft PVC， was listed as one of the top ten controlled substances in the rohs 2.0 revised directive (EU) 2015/863 issued in the OJ. The PVC polymer itself is generally regarded as being resistant under soil-buried and landfill conditions.[176] The stabilisers in rigid PVC are generally bound in the matrix of the polymer and do not leach out readily. PVC does not contribute significantly to the amounts of heavy metals stored in the landfill body, irrespective of any possible releases.[177]

389. Although the reported releases of cadmium, lead organotin and phtalates are considered to be of minor relevance in terms of quantities introduced and released in landfills or because of the retention capacity of the waste matrix and biodegradation in landfills, they are only controllable if landfills are equipped with adequate liner and leachate collection and treatment system.[178]

390. It is important also to consider the technical guidelines governing the environmentally sound recovery and disposal of wastes such as the draft updated technical guidelines for incineration on land (D10), the draft updated technical guidelines on specially engineered landfill (D5) (UNEP/CHW/OEWG.11/INF/19)11 and draft updated technical guidelines on use as a fuel (other than in direct incineration) or other means to generate energy (R1).9

H. Health and safety

391. Both the supplier and receiver of the materials should ensure that the following information is available, 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 waste;

(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 waste 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.

392. To improve the 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 extensive information on POP substances and hazardous substances listed in GHS (additives, polymers, etc.) used at the

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[175] DGXI, E. (1999). The behaviour of PVC in Landfill.

[176] Ibid.

[177] DGXI, E. (1999). The behaviour of PVC in Landfill.

[178] Ibid.

production step of the plastic. During the handling of packaging coming from the agriculture sector, the presence of pesticides is of particular concern.

393. Contaminated plastics such as packaging of pesticides or other hazardous chemicals should be handled with specific care. It can constitute a hazardous waste, depending on the type and amount of contamination, in which case the waste should be treated according to the requirements for hazardous waste.

394. In certain cases, it may be possible to remove contamination via a decontamination process. After an adequate decontamination process the plastic waste may be processed with technologies similar to those suitable for non-contaminated plastic waste, provided it is assured that the decontamination process has been effective. Residues from the decontamination process, in which the contaminants are concentrated, should be treated or be disposed of in an appropriate way. Wastewater from these processes may require treatment according to local legislation.

395. When plastic waste is contaminated with larger quantities of food residues problems with micro-organisms, odor and attraction of pests may occur.

396. The following should be noted, whenever possible:

(a) 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;

(b) Plastic wastes may become contaminated with water, insect pests and dirt during transport and storage if not properly protected.

397. For handling of plastic wastes from healthcare facilities, the technical guidelines on environmentally sound management of biomedical and healthcare wastes (Y1, Y3) should also be considered.

398. The following rules should always apply in the working condition:

(a) Smoking should be forbidden in plastics waste storage and processing areas and such areas should be protected by secure fencing;

(b) Ready access to all parts of the storage area 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 the storage area, but staff should attempt to extinguish fires only in their very earliest stages.

1. Fire and safety

399. 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:

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

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

2. Smoke and toxic gases

400. It is recognised that the major cause of deaths in accidental fires is the inhalation of carbon monoxide and smoke.[179] 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 whatever material are involved.

[179] Fardell. P., 1993, ‘Toxicity of plastics and rubber in fire’, RAPRA Review `Reports - No. 69.

401. Burning PVC and fluoropolymers emit acid gases but are much more difficult to ignite than other plastics and they burn very slowly. Hydrogen chloride released from burning PVC is considered by the firemen to have effects similar to carbon monoxide. Hydrogen fluoride from burning fluoro-polymers is more toxic than carbon monoxide but is unlikely to be present in any significant quantities.

402. The soot from burning materials, natural and man-made, contains small concentrations of more toxic materials and so it should be handled with care using appropriate protective clothing. Toxic materials are firmly bonded onto the surface of soot particles and so they are not very biologically active.[180]

403. For further information on data from fires in recycling plants see Appendix 5.

I. Emergency response

404. Emergency response plans should be in place for all 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 all plastic wastes on site;

(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.

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

J. Awareness and participation

406. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management[181] 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 environmentally sound

[180] German Federal Health Gazette. (N.d.) Recommendations for Cleaning buildings after fires. 1/90, 32-43.

[181] Basel Deglaration on Environmentally Sound Management. Available at: https://dig.watch/sites/default/files/ministerfinal.pdf.

management with regard to the enhancement of information exchange, education and awareness-raising in all sectors of society; and cooperation and partnership at all levels between countries, public authorities, international organizations, industry, non-governmental organizations and academic institutions.

407. 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) 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.

408. Public awareness and attitudes to plastic waste 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.

409. Separation and collection for enhancing recycling, energy recovery and final disposal of plastic wastes highly depends on the cooperation of consumers. Thus, public awareness rising and promoting public participation is especially critical for environmental sound management of plastic wastes.

410. Local authorities should organize awareness raising campaigns/events addressed to business (commercial, beach users, fishermen, etc.) and public (tourists, households, etc.) to make people aware of the importance of sustainable waste plastic management 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 to address them such as door to door information, leaflets, community meetings, media etc. Communication objectives could:[182]

(a) Address cultural practices and beliefs;

(b) Emphasize health benefits;

(c) Use simple messages and multiple media types;

(d) Build on existing neighborhood networks;

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

(f) Frame plastic waste management activities as a topic of great interest for voters;

(g) Increase visibility and credibility of plastic waste management activities (e.g., by issuing uniforms to workers) Identify instances where city activities support national goals;

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

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

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

IV. Special consideration of degradable plastic waste

411. In the late 1980s, several US plastics companies began to market products that were "degradable" (they were intended to last in the environment for less than the life-span of normal plastics). Degradation meant the loss of properties, such as physical strength and integrity, not necessarily the total elimination of polymeric structures.[183, 184]

[182] CCAC, "Raising Awareness about Solid Waste Management," 2013.

[183] Greene, K. L., & Tonjes, D. J. (2014). Degradable plastics and their potential for affecting solid waste systems. *WIT Transactions on Ecology and the Environment*, *180*, 91-102. Available at: https://www.witpress.com/Secure/elibrary/papers/WM14/WM14008FU1.pdf.

[184] Kalia, S., & Avérous, L. (2016). *Biodegradable and Biobased Polymers for Environmental and Biomedical Applications*. John Wiley & Sons.

412. Degradation of plastics refers to the process of significant changes in structure and loss of performance under the influence of environmental conditions (temperature, humidity, water, oxygen, etc.). It can be divided into mechanical degradation, biodegradation, photodegradation, thermal oxygen degradation and photooxygen degradation.

413. Whether a plastic can be completely biodegraded is affected by many factors, including crystallinity, additives, microorganisms, temperature, humidity, environmental pH value and time. In the absence of conditions, many degradable plastics not only cannot achieve complete biodegradation, but also may have a negative impact on the environment and human health. For example, under the action of additives, some of the oxygen degradation plastics only break up and degrade into invisible plastic particles.

414. Often, there is a confusion in the differences among the terms, bioplastics, biodegradable plastics, compostable and oxo-degradable plastics. Therefore, we need to clearly define and standardize the identification of biodegradable plastics.

415. Bio-plastics or bio-based plastics are plastics made wholly or partily from renewable biological resources - most often vegetable – which are either biodegradable or not. Bio-plastics encompass a large number of materials that are either bio-sourced or biodegradable or both.[185]

416. There are different labels in place indicating whether a product is bio-based. Some indicate the biobased ratio as well. Examples of such lables are provided in Appendix 10.

417. Bio-based plastics is a kind of plastics which takes starch, soybean, cellulose, lignin, vegetable oil and other renewable resources as raw materials. It focuses on the bio source and renewable of raw materials. Such plastics include both degradable or compostable plastics and non degradable plastics; there are both thermoplastic and thermosetting resins. Bio-based plastics can be categorized as drop-in plastics (have the ability to be exchanged directly with their fossil counter-part) or novel plastics (have a chemical structure like no other).

418. A biodegradable plastic is one that can be decomposed under the action of microorganisms (bacteria, fungi, algae, etc.). The result is the formation of water (H2O), carbon dioxide (CO2) and/or methane (CH4), and by-products (residues, new biomass) that are not toxic for the environment. This consensual definition is used in at least five applicable standards (ISO, CEN) , including the European and French standard NF EN 13432 as to requirements for "packaging recoverable by composting and biodegradation".

419. Biodegradable plastic refers to the plastic that can be degraded under certain conditions by microorganisms in nature, such as bacteria, mould and algae, and finally turn into water or carbon dioxide and other small molecules to enter the natural circulation. It is equivalent to the plastic that can be degraded or composted as referred to by the European Plastics Association.

420. Compostable plastics are a subset of biodegradable plastics that biodegrade in a composting environment yielding water, CO2 and biomass and can be plant based but they can be petroleum based as well. The biodegradability does not depend on the raw material but entirely on the chemical structure of the polymer chains. BASF® Ecoflex® and MATER-BI Novamont are a good examples of a compostable polymers, which are compostable at industrial compost facilities.[186]

421. 'Oxo-degradable', 'oxydegradable' or 'oxo-biodegradable' plastics are conventional plastics such as polyethylene (PE) which include an additive to help them break down fragments and should not be confused with the biodegradable plastics.[174] Oxo-degradable plastic bags is one example, which break down in smaller pieces that could lead to microplastics leakage in the environment.

422. Bio-based and biodegradable plastics can be divided into three categories:[187]

(a) Biodegradable bio-based plastics: PLA, PHAs, starch blends, bio-PBS(A);

[185] The Norwegian Environment Agency, 2018, Bio-Based and Biodegradable Plastics. Retrieved from: http://tema.miljodirektoratet.no/Documents/publikasjoner/M1206/M1206.pdf.

[186] Sphere and Kaneka Belgium NV, 2019, Biodegradable and Compostable Bioplastics, Situational Analysis, Retrieved from: https://www.sphere.eu/wp-content/uploads/2019/09/18072019-Rapport-SPHERE-ANG-DEF.pdf.

[187] Hann, S., Scholes, R. (2018). Bio-Based and Biodegradable Plastics. An Assessment of the Value Chain for BioBased and Biodegradable Plastics in Norway.

(b) Biodegradable fossil-based plastics: PBAT, PBS(A), PCL, PVA;

(c) Non-biodegradable bio-based plastics: bio-PET, bio-PE, PEF, bio-PP, bio-PAs, PTT.

423. The most common, successful degradable resins are poly-lactic acid (PLA), polyhydroxyalkanoate (PHA), and starch-based polymers-polybutylene succinate (PBS). With flexibility in their properties, PLA, PHAs, and PBS can potentially substitute conventional plastics such as polypropylene (PP), polyethylene terephthalate (PET), and polystyrene (PS).

424. PLA is synthesised by either condensation polymerization azetropic dehydrative condensation of lactic acid, or by ring-opening polymerization of lactide. PLA's monomer, lactic acid, is obtained by chemical synthesis or fermentation of carbohydrate.[188] PLA applications are various. They are uses in 3D printers as a feedstock material as well as medical implants as well as a decomposable packaging material. Cups and bags have been made from this material. Moreover PLA has been used as raw material foragricultural mulch films.

425. 50% - 60% humidity and 100℃ 50-70℃ are two basic conditions for PLA biodegradation. Under these conditions, it is possible for microorganisms to gradually decompose PLA over a period of months or even longer. From another point of view, PLA cannot be degraded in the environment that does not meet the temperature and humidity conditions.

426. PLA does not degrade rapidly when leaked into the environment as litter on land or the ocean. It degrades rapidly only when it ends up in a commercial composting facility.[189]

427. PHA polymers are polyesters synthesized inside microorganisms in a carbon-augmented environment through bacterial fermentation of sugars or lipids[190] Polyhydroxyalkanoates-based bioplastic formulations are used for food packaging applications. However, there is a main obstacle for the market uptake of PHA which has to do with its higher price compared to other bioplastics.[191]

428. PBS is a synthetic polyester synthesized from dicarboxylic acids and glycol. PBS could be utilised in electronics and other consumer goods applications. In addition, it could have various (food) packaging applications such as for cups and plates. Due to its biodegradability nature (according to DIN EN 13432) PBS could be used for applications at which compostability is signinficant. Such an example are the agricultural mulch films.[192]

429. Global production of bioplastics (both biodegradable and non-biodegradable) has increased from 0.7 million tonnes in 2010 to 2.11 million tonnes in 2018 with Asia being the hub of bioplastics. In 2018 bioplastics accounted for only 0.6% of total plastic production, 57% of which are non-biodegradable.[193]

430. In relation to the production of packaging, conventional plastics are being replaced by bioplastics at an extent. Bioplastic packaging options include bags for compost, agricultural foils, horticultural products, nursery products, toys and textiles. They are also often used for disposable cups, salad bowls, plates, cling film and food containers[194] (see Table 16).

[188] Milena S. Lopes , André L. Jardini and Rubens M. Filho.(2014). *Synthesis and Characterizations of Poly (Lactic Acid) by Ring-Opening Polymerization for Biomedical Applications*. Available at: https://www.aidic.it/cet/14/38/056.pdf.

[189] Pending reference from Plastics Europe.

[190] Khanna, S., & Srivastava, A. K. (2005). Recent advances in microbial polyhydroxyalkanoates. *Process biochemistry*, *40*(2), 607-619.

[191] EU (2017).Bioplastics: Sustainable materials for building a strong and circular European bioeconomy. Available at: https://ec.europa.eu/research/bioeconomy/pdf/cordis_rp_bioplastics_brochure_accessibility_v2.pdf.

[192] Succinity, Biobased Polybutylene Succinate (PBS) – An att racti ve polymer for biopolymer compounds. Avaialable at: http://www.succinity.com/images/succinity_broschure.pdf.

[193] European bioplastics, 2019, Bioplastics. Facts and Figures. Retrieved from: https://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf.

[194] Shah, A.A., Hameed, A., Hasan, F., Ahmed, S., Biological degradation of plastics: A comprehensive review, Biotechnology Advances, 26, 246-265, 2008.

Table 16: Uses of bio-based biodegradable plastics. Adopted from [183]

Plastics	Uses
Polyglycolic acid (PGA)	Specialized applications; controlled drug releases; implantable composites; bone fixation parts
Polylactic acid (PLA)	Packaging and paper coatings; other possible markets include sustained release systems for pesticides and fertilizers, mulch films, and compost bags
Polycaprolactone (PCL)	Long-term items; mulch and other agricultural films; fibers containing herbicides to control aquatic weeds; seedling containers; slow release systems for drugs
Polyhydroxybutyrate (PHB)*	Products like bottles, bags, wrapping film and disposable nappies, as a material for tissue engineering scaffolds and for controlled drug release carriers
Polyhydroxyvalerate (PHBV)	Films and paper coatings; other possible markets include biomedical applications, therapeutic delivery of worm medicine for cattle, and sustained release systems for pharmaceutical drugs and insecticides
Polyvinyl alcohol (PVOH)	Packaging and bagging 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 remoistenable label

431. Concerning the options of managing bio-based and biodegradable plastic wastes, there are a few considerations from academics. When applications and the market of bio-based and biodegradable plastics will increase then there will also be an increase of their presence in waste streams and as such enter the established recycling processes for fossil-based plastics. As sorting of plastics in most cases based on appearance (visual discrimination) it would lead such materials to be treated in the same units along with conventional plastic wastes or organic wastes.

432. Even in mechanical recycling facilities there might be a risk that mechanical sorting techniques would not be able to sort out biobased and biodegradable plastics. For instance a bottle made from PET and from PLA is not possible to separate by appearance since both materials are transparent and very similar. Also, PLA is denser than water so in the flotation tank any PLA fragments will eventually follow the PET stream towards mechanical recycling. This mixing of PLA with PET materials would cause problems to the reprocessing unit since PLA and PET have different melting point.[195] Composting of bio-based compostable plastic in a composting facility has a risk of attracting other non-compostable plastics to this facility with a risk of technical problems on the composting activity. In addition, biodegradable plastics may not breaking down in time in the composting facility. [more text to be provided]

433. Although bio-based plastics have been reported to have lower environmental impacts in terms of greenhouse gas emissions and fossil depletion than their conventional plastic counterparts[196] however this is not always the case. The Oregon Department of Environmental Quality did a life cycle assessment and report on different types of packaging and service wear and which concluded that biobased or compostable doesn't always guarantee lower environmental impact. It depends on what the sources are (which may require higher fossil fuel use while being grown) and how much energy and water are required in production.[197]

434. For the bio-based plastics to be practically viable, consideration of environmental impacts alone may not be sufficient. There are limited studies that are assessing the three axis of sustainability (economic, social and environmental aspects) in biobased products.[198] Optimization of economics and high efficiency are required for the overall production process of bio-based products to be competitive to that of fossil feedstock-based products, combined

[195] Luc Alaerts, Michael Augustinus ID and Karel Van Acker, (2018)., Impact of Bio-Based Plastics on Current Recycling of Plastics.

[196] Kunnika Changwichan,Thapat Silalertruksa, and Shabbir H. Gheewala, (2018) Eco-Efficiency Assessment of Bioplastics Production Systems and End-of-Life Options.

[197] https://www.oregon.gov/deq/mm/production/Pages/Materials-Attributes.aspx.

[198] Changwichan, K., Silalertruksa, T., & Gheewala, S. (2018). Eco-efficiency assessment of bioplastics production systems and end-of-life options. *Sustainability*, *10*(4), 952. Available at https://www.mdpi.com/2071-1050/10/4/952/htm.

with minimization of negative environmental impact. Therefore there is a need of developing a universal methodology on techno-economic analysis aiming at providing a quantitative and qualitative analysis of the impact of technological advances and the economy-of-scale on the financial viability of the conversion of biomass and processing to materials and products, their use and their waste management.[199]

435. The use of biodegradable plastics instead of non-biodegradable plastics does not change the behavior of the citizen about the attitude towards littering of waste. A mind shift of collecting and treatment of the waste is also necessary.

[199] Tsakona M.,Koutinas A. add Ladakis D. (2018), Available at: The gap in techno-economic sustainability assessment of bio-products: from open loops to close loops. https://www.iswa2019.org/wp-content/uploads/2019/11/PROCEEDINGS2019.pdf, page 88-89.

APPENDIX 1

List of different microorganisms reported to degrade different types of plastics. Adapted from[201]

Synthetic Plastics		
Plastic	**Microorganism**	**Reference**
Polyethylene	Brevibacillus borstelensis Rhodococcus rubber Penicillium simplicissimum YK	Hadad et al. (2005)[202] Sivan et al. (2006);[203] Gilan et al., 2014[204] Yamada-Onodera et al., 2001[205]
Polyurethane	Comamonas acidovorans TB-35 Curvularia senegalensis Fusarium solani Aureobasidium pullulans Cladosporium sp. Pseudomonas chlororaphis	Akutsu et al., 1998[206] Howard (2002)[207] Zheng et al. (2005)[208]
Polyvinyl chloride	Pseudomonas putida AJ Ochrobactrum TD Pseudomonas fluorescens B-22 Aspergillus niger van Tieghem F-1119	Antony et al. (2004)[209] Mogil'nitskii et al. (1987)[210]
Plasticized Polyvinyl chloride	Aureobasidium pullulans	Webb et al. (2000)[211]
BTA-copolyester	Thermomonspora fusca	Kleeberg et al. (1998)[212]
Natural plastics		
Poly(3-hydroxybutyrate-co-3-mercaptopropionate)	Schlegelella thermodepolymerans	Elbanna et al. (2004)[213]
Poly(3-hydroxybutyrate)	Pseudomonas lemoignei	Jendrossek et al. (1995)[214]
Poly(3-hydroxybutyrate-co-3-mercaptopropionate)	Pseudomonas indica K2	Elbanna et al. (2004)[213]

[201] Shah, A.A., Hameed, A., Hasan, F., Ahmed, S., Biological degradation of plastics: A comprehensive review, Biotechnology Advances, 26, 246-265, 2008.

[202] Hadad D, Geresh S, Sivan A. Biodegradation of polyethylene by the thermophilic bacterium Brevibacillus borstelensis. J Appl Microbiol 2005;98:1093–100.

[203] Sivan A, Szanto M, Pavlov V. Biofilm development of the polyethylenedegrading bacterium Rhodococcus ruber. Appl Microbiol Biotechnol 2006;72(2):346–52.

[204] Gilan I, Hadar Y, Sivan A. Colonization, biofilm formation and biodegradation of polyethylene by a strain of Rhodococcus ruber. Appl Microbiol Biotechnol 2004;65:97–104.

[205] Yamada-Onodera K, Mukumoto H, Katsuyaya Y, Saiganji A, Tani Y. Degradation of polyethylene by a fungus. Penicillium simplicissimum YK. Poly Degrad Stab 2001;72:323–7.

[206] Akutsu Y, Nakajima-Kambe T, Nomura N, Nakahara T. Purification and properties of a polyester polyurethane-degrading enzyme from Comamonas acidovorans TB-35. Appl Environ Microbiol 1998;64:62–7.

[207] Howard GT. Biodegradation of polyurethane: a review. Int Biodeter Biodegrad 2002;40:245–52.

[208] Zheng Y, Yanful EK, Bassi AS. A review of plastic waste biodegradation. Cri Rev Biotechnol 2005;25:243–50.

[209] Anthony SD, Meizhong L, Christopher EB, Robin LB, David LF. Involvement of linear plasmids in aerobic biodegradation of vinyl chloride. Appl Environ Microbiol 2004;70:6092–7.

[210] Mogil`nitskii GM, Sagatelyan RT, Kutishcheva TN, Zhukova SV, Kerimov SI, Parfenova TB. Disruption of the protective properties of the polyvinyl chloride coating under the effect of microorganisms. Prot. Met. (Engl. Transl.) 1987;23:173–5.

[211] Webb JS, Nixon M, Eastwood IM, Greenhalgh M, Robson GD, Handley PS. Fungal colonization and biodeterioration of plasticized polyvinyl chloride. Appl Environ Microbiol 2000;66(8):3194–200.

[212] Kleeberg I, Hetz C, Kroppenstedt RM, Deckwer WD. Biodegradation of aliphatic-aromatic copolyesters by Thermomonospora fusca and other thermophilic compost isolates. Appl Environ Microbiol 1998;64:1731–5.

[213] Elbanna K, Lütke-Eversloh T, Jendrossek D, Luftmann H, Steinbüchel A. Studies on the biodegradability of polythioester copolymers and homopolymers by polyhydroxyalkanoate (PHA)-degrading bacteria and PHA depolymerases. Arch Microbiol 2004;182(2–3):212–25.

[214] Jendrossek D, Frisse A, Andermann M, Kratzin HD, Stanislawski T, Schlegel HG. Biochemical and molecular characterization of the Pseudomonas lemoignei polyhydroxyalkanoate depolymerase system. J bacteriol 1995;1773:596–607.

Synthetic Plastics		
Plastic	**Microorganism**	**Reference**
Poly(3-hydroxybutyrate) Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)	Streptomyces sp. SNG9	Mabrouk and Sabry (2001)[215]
Poly(3-hydroxybutyrate-co-3-hydroxypropionate)	Acidovorax sp. TP4	Wang et al. (2002)[216]
Poly(3-hydroxybutyrate) poly(3-hydroxypropionate) poly(4-hydroxybutyrate) poly(ethylene succinate) poly(ethylene adipate)	Alcaligenes faecalis Pseudomonas stutzeri Comamonas acidovorans	Kasuya et al. (1999)[217]
Poly(3-hydroxybutyrate)	Alcaligenes faecalis	Kita et al. (1997)[218]
Poly(3-hydroxybutyrate)	Schlegelella thermodepolymerans Caenibacterium thermophilum	Romen et al. (2004)[219]
Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)	Clostridium botulinum Clostridium acetobutylicum	Abou-Zeid et al. (2001)[220]
Polycaprolactone	Clostridium botulinum Clostridium acetobutylicum	Abou-Zeid et al. (2001)[220]
Polycaprolactone	Fusarium solani	Benedict et al. 1983[221]
Polylactic acid	Fusarium moniliforme Penicillium roquefort Amycolatopsis sp Bacillus brevis Rhizopus delemer	Torres et al. 1(996)[222] Pranamuda et al. (1997)[223] Pranamuda and Tokiwa (1999)[224] Tomita et al. (1999)[225] Fukuzaki et al (1989)
Polymer blends		
Starch/polyethylene	Aspergillus niger Penicillium funiculosm Phanerochaete chrysosporium	Lee et al (1991)[226]
Starch/polyester	Streptomyces Phanerochaete chyrsosporium	Lee et al (1991)[226]

[215] Mabrouk MM, Sabry SA. Degradation of poly(3-hydroxybutyrate) and its copolymer poly(3-hydroxybutyrate-co-3-hydroxyvalerate) by a marine Streptomyces sp. SNG9. Microbiol Res 2001;156:323–35.

[216] Wang Y, Inagawa Y, Saito T, Kasuya K, Doi Y, Inoue Y. Enzymatic hydrolysis of bacterial poly(3-hydroxybutyrate-co-3-hydroxypropionate)s by poly(3- hydroxyalkanoate) depolymerase from Acidovorax Sp. TP4. Biomacromolecules 2002;3(4):828–34.

[217] Kasuya T, Nakajima H, Kitamoto K. Cloning and characterization of the bipA gene encoding ER chaperone BiP from Aspergillus oryzae. J Biosci Bioeng 1999;88(5):472–8.

[218] Kita K, Mashiba S, Nagita M, Ishimaru K, Okamoto K, Yanase H, Kato N. Cloning of poly(3-hydroxybutyrate) depolymerase from a marine bacterium, Alcaligenes faecalis AE122, and characterization of its gene product. Biochim Biophys Acta 1997;1352:113–22.

[219] Romen F, Reinhardt S, Jendrossek D. Thermotolerant poly(3-hydroxybutyrate)- degrading bacteria from hot compost and characterization of the PHB depolymerase of Schlegelella sp. KB1a. Arch Microbiol 2004;182:157–64.

[220] Abou-Zeid DM., Müller RJ, Deckwer WD. Anaerobic biodegradation of natural and synthetic polyesters, Dissertation, Technical University Braunschweig, Germany, 2001. Internet:http://opus.tu-bs.de/opus/volltexte/2001/246.

[221] Benedict CV, Cameron JA, Samuel J. Polycaprolactone degradation by mixed and pure cultures of bacteria and a yeast. J Appl Pol Sci 1983;28:335–42.

[222] Torres A, Li S, Roussos S, Vert M. Screening of microorganisms for biodegradation of poly (lactic acid) and lactic acid-containing polymers. Appl Environ Microbiol 1996;62:2393–7.

[223] Pranamuda H, Tokiwa Y, Tanaka H. Polylactide degradation by an Amycolatopsis sp. Appl Environ Microbiol 1997;63:1637–40.

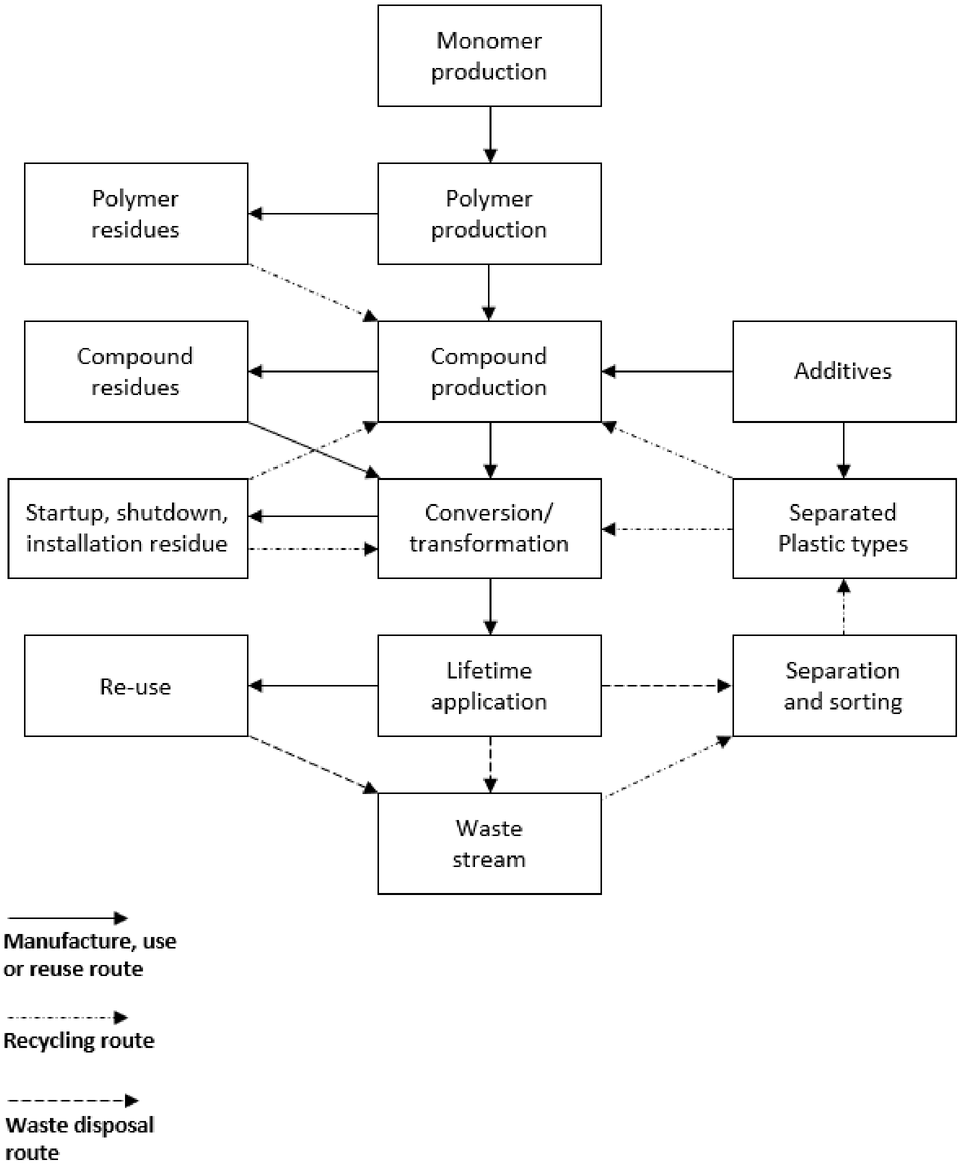
[224] Pranamuda H, Tokiwa Y. Degradation of poly (l-lactide) by strains belonging to genus Amycolatopsis. Biotechnol Lett 1999;21:901–5.

[225] Tomita K, Kuraki Y, Nagai K. Isolation of thermophiles degradating poly (L-lactic acid). J Biosci Bioeng 1999;87:752–5.

[226] Lee B, Pometto AL, Fratzke A, Bailey TB. Appl Environ Microbiol 1991;57: 678–85.

APPENDIX 2

Manufacture, Use, Reuse and Recycling of Plastics



APPENDIX 3

Material Identification Marking for packaging

When it comes to recycling, plastics are categorized according to their chemical properties, physical properties, and the polymer types from which they are made. The ASTM International Resin Identification Coding (RIC) System, is a set of symbols appearing on plastic products that identify the plastic resin out of which the product is made. It was developed in 1988 by the Society of the Plastics Industry, but since 2008 it has been administered by ASTM International, an international standards organization.[227] The symbols used in this coding system are illustrated below.

Resin Identification Number	Resin	Resin Identification Code –Option A	Resin Identification Code –Option B
1	Poly(ethylene terephthalate)	1 PETE	01 PET
2	High density polyethylene	2 HDPE	02 PE-HD
3	Poly(vinyl chloride)	3 V	03 PVC
4	Low density polyethylene	4 LDPE	04 PE-LD
5	Polypropylene	5 PP	05 PP
6	Polystyrene	6 PS	06 PS
7	Other resins	7 OTHER	07 O

For non-packaging applications the marking on plastics components is likely to be marked according to ISO 11469:2016, Plastics - Generic identification and marking of plastics products.

[227] ASTM Plastics Committee Releases Major Revisions to Resin Identification Code (RIC) Standard, https://www.astm.org.

APPENDIX 4

Health & Safety Information for

Materials Reclamation Facilities (MRF)

(This has wider application than just for plastics)

1 Safety Information

The following information should form part of the site Health and Safety manual. This information refers in particular to the operation of the equipment supplied for the storage, sorting and baling of plastics waste. It is recommended that the procedures outlined in the safety manual are reviewed regularly to ensure that the information is appropriate and relevant to the equipment and working practices in the MRF.

It is recommended that the information contained within the safety manual should form part of the training of personnel employed within the MRF and also that sections of the information are made available to those activities associated with the MRF such as transport of materials to and from the MRF and the reception of visitors.

1.1 It may be necessary to harmonise some of these recommendations with existing site rules and local regulations.

1.2 These safety instructions apply to those involved with the operation of the MRF and visitors.

1.3 All personnel involved in the operation of the MRF including those involved in the delivery and despatch of materials should be made aware of, and agree to, observe the safety instructions outlined in the site 'Safety Manual'.

2 Fire

2.1 The emergency services should be made aware of the types and quantities of recyclates being stored.

2.2 The potential danger of fire, when dealing with waste plastics is high. Materials should only be stored in agreed and defined areas.

2.3 A "No Smoking" policy should be established and enforced in the MRF for everybody - including visitors and contractors.

2.4 Emergency escape routes to a defined assembly point, external to the building or site, should be clearly identified by notices and always kept free.

2.5 Suitable fire extinguishers should be provided both within the MRF and in the storage areas. Staff should be trained in the use of fire fighting equipment.

2.6 The need for “good operating practices” is paramount, in order to maintain good working conditions, high standards of hygiene, and to avoid the unnecessary storage of flammable materials/waste.

2.7 Flammable liquids and gases should not be stored within the MRF or storage areas.

2.8 An emergency fire alarm system should be available and regularly tested once per week. UNEP/CHW.6/21

2.9 Evacuation routes should be established and evacuation procedures should be practiced.

2.10 All personnel should be aware of the emergency procedures in the event of a fire. It is recommended that an emergency telephone should be located within the MRF and that numbers for local emergency services should be clearly displayed.

3 Accidents

3.1 In areas where there is machinery and/or many vehicle movements there is a higher potential for accidents. Adherence to safe working practices, the regular maintenance of equipment and the appropriate training of personnel will help to minimise accidents.

3.2 Personnel working in the MRF have a duty to ensure that they do not endanger themselves or others. Particular care must be taken when there are visitors on the site.

3.3 Safe working practices and instructions must be observed at all times. Only fully trained personnel should operate the MRF machinery.

3.4 Fork truck/loading shovel drivers should be trained and should hold the appropriate licence or certificate.

3.5 At least two members of staff should be trained in basic first-aid procedures. First-Aid boxes, suitably equipped and adjacent to a sink should be provided.

3.6 Operators should wear appropriate clothing. Additional protection should be provided for certain conditions outlined below:

- Head protection is needed if staff are working in areas where tipping of mater ials occurs and where materials could fall from higher levels.
- Face and eye protection is needed if there is a risk from corrosive or irritant substances or impact from moving objects.
- Respiratory protection is needed if staff are subject to dust, fumes or vapours.
- Hand protection is needed to protect against sharp irritant or corrosive materials.
- It is recommended that supervisory management working in the MRF wear and use the appropriate personnel protection clothing, to set an example and to emphasise the standards required.

3.7 Personnel sorting recyclables are advised to be inoculated against tetanus infection.

3.8 Equipment maintenance should be carried out as recommended by the supplier and only by trained technicians. On no account should protective guards or shields be removed, unless for authorised maintenance.

3.9 The safety stop systems employed on the equipment be tested each week.

3.10 Personnel should not climb on protective fences.

3.11 Foolish behaviour should not be permitted.

4 Baling Machines and Bales

4.1 The manufacturers operating instructions must be strictly observed. Incorrect use of baling equipment can lead to potentially very dangerous situations.

4.2 If strapping of bales is not carried out properly or there is a defect in the strapping material the bale strapping can fail. In the event that this occurs the bale can expand rapidly. If this occurs before or during the release of the bale door, the force of the expanding bale can cause the baler door (where fitted) to open at a dangerous speed.

4.3 Only the approved specification of strapping should be used.

4.4 Servicing of the baler should only to be carried out by an authorised maintenance engineer.

4.5 No unauthorised alterations to the baler should be made.

4.6 All balers used for baling plastic bottles should be fitted with an hydraulic baler door speed restriction device.

4.7 A yellow striped restricted area should be marked around the baling machine. This area should only be entered by MRF operators involved in the strapping and removal of baled materials.

4.8 Should it be necessary to cut the high tension steel strapping great care should be exercised and only approved safety cutters should be used.

4.9 Bales typically weigh between 200-400 kg depending upon the density of materials. Adequate handling equipment is essential. Bales should be moved from the baling machine by hand pallet trucks or fork lift trucks. A fork lift truck should be used for local transport and stacking.

4.10 Bales should not be stored more than three bales high. Fork trucks should have side clamp units fitted to their forks for the safe movement and stacking of bales.

4.11 Visitors on the site should not be allowed in areas in which bales are stacked.

5 Baler Maintenance (Cleaning, Removal of Materials)

5.1 Before any maintenance work is carried out on the balers, the power must be switched off and the machine isolated electrically.

5.2 Baling machines occasionally need to be cleaned internally as a result of continual use or as a result of contamination. No operator should ever enter a baling machine without first gaining approval from the supervisor.

5.3 The supervisor should ensure that the mains electricity is isolated and locked off with a padlock system. The supervisor should retain the key. Any residual hydraulic power should be released in the event that hydraulic accumulators are used within the baling machine hydraulic circuit.

5.4 A notice should be placed on the machine clearly identifying that an operator is cleaning/maintaining the machine. Removal of the notice and restoration of power should ONLY be undertaken by the supervisor when the operator is safely clear of the machine and the machine is in a safe condition to enter service.

5.5 Always take special care when operating the door locking mechanism to avoid personal injury.

5.6 Keep all parts of the body clear of the door locking mechanism.

6 Intermediate Storage Skips

6.1 Care should be taken when moving these skips to ensure that clear driver/operator visibility is maintained.

6.2 Parked skips should not obstruct any emergency exit routes, or working areas.

6.3 Intermediate storage skips should only be stacked two units high.

6.4 Ensure that the entry to any baler feed pit is closed and secured after baling operations.

7 Supervisor

7.1 It is recommended that the supervisor of the MRF should be a person active within the facility on a daily basis.

7.2 The supervisor should allow only fully trained people to work in the MRF.

7.3 In addition to operator safety, the supervisor has the following areas of responsibility.

7.4 Before switching on the MRF equipment, the supervisor should ensure that it is not obstructed and that personnel are well clear of all moving par ts. Alarm systems should be installed to provide advanced warning of machinery start-up.

7.5 The supervisor should be trained in fire drill and first aid procedures, the methods of contacting the emergency services, the emergency access and escape routes , and should ensure that the first aid equipment is in a clean and well stocked state. A site accident book should be available and it should be used to record any accidents or potentially hazardous situations. Emergency escape routes should be inspected regularly to ensure that they are kept clear.

7.6 The supervisor should insist that good housekeeping standards are maintained. Areas of tipped materials, gangways and fire escapes should be defined and kept clear at all times.

7.7 The supervisor should ensure that there is no foolish behaviour on the premises.

7.8 There should be emergency lighting and it should be regularly tested.

7.9 At the end of the operational shift, the supervisor should ensure that all power is switched off, that all people are clear of the site and that the site is locked and secured before leaving.

8 Operators

8.1 The following instructions have been written specifically for the operators, however, they should be read in conjunction with the other local site instructions.

8.2 fully trained personnel should operate the MRF machinery.

8.3 Operators must not wear loose items of clothing and long hair should be retained by suitable head gear and kept away from moving equipment.

8.4 Protective clothing should be worn when working on the sort line, or as required in other areas.

8.5 On no account should operators climb upon conveyor belts.

8.6 On no account should operators enter sorting chutes.

8.7 On no account should operators enter material feed pits.

8.8 On no account should operators enter the baling machines.

8.9 In the event of an emergency situation the operator should activate the emergency stop system and not attempt to free the machinery until the equipment has been switched off and isolated.

8.10 Operators should at all times be aware of vehicle movements within the MRF.

8.11 Any hazardous situation should be reported immediately to the supervisor.

9. Visitors

9.1 The site supervisor should organise and supervise any site visit.

9.2 The tour guide of any visit should be conversant with the safety instructions for the site.

9.3 No visitor should touch or operate machinery. They must be advised of and agree to obey all safety instructions such as fire evacuation procedures and no smoking rules, etc. before entering the MRF.

9.4 Vehicle movements and other operations of a potentially hazardous nature should not be undertaken during a visit.

9.5 The MRF supervisor should ensure that visitors remain within specified areas of the MRF.

9.6 A record of individuals entering the MRF should be kept using an entry/exit log system.

9.7 Visitors should be provided with appropriate safety protection eg. safety spectacles, hearing protection and high visibility jackets.

APPENDIX 5

A. Data from fires at German recycling plants

At **Mulheim** in the Ruhr valley, a warehouse belonging to a haulage contractor was burned out in a major fire. The fire consumed 340 tonnes of PVC and 150 tonnes of polyethylene. The regional office for environmental protection carried out a careful examination of the pollution caused by the fire. It was concluded that the fire gases contained less dioxins than is emitted by many refuse incinerators.

A second fire in 1992, at **Lengerich**2 in North Rhein Westphalia, in a plastics recycling plant, consumed 1500 tonnes of plastics including 500 tonnes of PVC. Both the local authorities and the regional Environmental Ministry were involved in the investigation of dioxin emissions. The regional Environmental Ministry published a press release which listed the following key conclusions:

· Offices and dwelling houses up to 100 metres from the fire were examined, giving no cause for concern

· Neither the sewage treatment plant nor the ground water seemed unsafe

· Root crops were declared safe and only leaf crops were subject to a single season ban on consumption

· The 26 people most exposed to the fire gases showed low blood-dioxin levels

· A wider university study confirmed that no one was significantly contaminated

· Similar conclusions were drawn from 4 other major fires at Grossefahn, Achim, Siegburg and Ishy

These conclusions correspond well with the results of a study of firefighters carried out by the Universities of Bochum and Düsseldorf on the instructions of the NRW Ministry of Labour, Health and Environment.

Ministry of the Environment, Planning and Agriculture, North Rhine-Westphalia, Germany, 1994.

B. Data from fire at the Hamilton Plastimet recycling plant

The fire at the Plastimet recycling facility was a devastating event for the entire community of Hamilton. It was a preventable incident that could have been avoided had the facility met the national Fire Code regulations governing the storage of plastic materials. When stored and handled properly, plastic recycling including vinyl, are safe and provide many benefits for the environment.

The Ontario Ministry of the Environment and Energy (MOEE) response to the Plastinet fire was timely and appropriate, an internal review committee has concluded. Its technical report analys ed the results of 8,500 samples by the MOEE on 500 samples of air (using trace atmospheric gas analysers), water, soil, soot and vegetation. The report found that with days after the fire was extinguished, ambient levels of substances tested returned to normal ranges, except in situations where prior contamination of soil and storm sewer water existed.

2 ‘Documentation on a major fire at Lengerich’, Ministry of the Environment, Planning and Agriculture, North Rhine-Westphalia, Germany, 1994.

The fire lasted three days (Wednesday-Friday, July 9-12, 1997). There was no evacuation the first two days due to weather conditions which allowed the fire’s smoke plume to go directly into the upper atmosphere. It was not until Friday when the weather forecasts indicated a wind shift (inversion) coming, which could pose a problem to surrounding residents, that it was decided to evacuate 650 nearby residents from their home on a voluntary basis as a precaution. Levels of benzene had also increased. This was subsequently carried out on Friday and residents then were allowed to return home less than 24 hours later after the fire had been successfully extinguished.

MOEE have collected samples for analysis: air, soot fallout, soil and vegetation. The Medical Officer of Health advised residents to not eat garden vegetables which cannot be peeled.

Technical Report released by the Ontario Ministry of the Environment and Energy 30 October 1997

C.Data from fire at Creswell, Derbyshire plastic recycling facility[1]

1 https://books.google.gr/books?id=6qHWCgAAQBAJ&pg=PA614&lpg=PA614&dq=fires+in+plastic+recycling+plants+hazards&source=bl&ots=5aJ61O8Xtr&sig=ACfU3U0DJ_3ihEDYTxXI9kfTP4778vI87w&hl=el&sa=X&ved=2ahUKEwjO-amUreXoAhWx5KYKHQ6GBRQ4ChDoATAFegQICxAq#v=onepage&q=fires%20in%20plastic%20recycling%20plants%20hazards&f=false.

On April 2002 a large plastics recycling plant in Creswell, Derbyshire, got fire and the public health services were noticed. The fire had initially produced copious quantities of thick, black smoke, which had dissipated quite rapidly. The burning plastic produced dense clouds of black smoke and generated potentially toxic products of combustion in an open environment, but there was no risk of explosion. Only few complaints of adverse health effects were received at the time and calls to all the health facilities in the area, including GPs, the GP co-op, NHS Direct and local emergency departments, revealed that there had been no reports of ill health.

D. Data from fire at Industrial plastics facility[2]

The Industrial Plastics facility that accumulates and recycles various types of plastics caught fire on December 18, 2013. The facility is located on a U.S. Environmental Protection Agency (EPA) National Priorities List (NPL) Superfund Site, known as the Wrigley Charcoal Superfund Site.

Air monitoring conducted during the approximately 30 hours of the emergency response at all locations. All oxygen levels measured during each of the 3 days of air monitoring were within the necessary range between 19.5 and 23%. Lower explosive limit measurements were not detected. Therefore, none of the potentially released gases caused explosive conditions onsite or off-site.

The many physical differences between children and adults demand special emphasis. Children could be at greater risk than adults from certain kinds of exposure to hazardous substances (ATSDR 1997, 1998). Children have lower body weights than adults. Although children's lungs are usually smaller than adults, children breathe a greater relative volume of air compared to adults. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage.

E. Data from fire at Connecticut recycling facility[3]

In January 2018, an enormous blaze broke out at a waste transfer station in Willimantic, Connecticut, about 30 miles outside of Hartford. The plume of thick, black smoke rising from the family-owned Willimantic Waste Paper Company's 100,000-square-foot facility was so large that it registered on weather radar maps. It took about 200 firefighters from 14 fire companies over 20 hours to get the fire under control. Although the building had a working sprinkler system and was up to code, according to the Associated Press, it was a total loss.

There are challenges and fire risks that may be present, and in this case, the following were included:

- long-smoldering fires due to lack of defined storage piles and limited aisle space
- lack of or ineffective sprinkler protection due to haphazard storage arrangements that do not lend themselves to normal sprinkler designs
- incompatible commodities (paper, plastics, combustible metals) stored in the same pile
- environmental impact on the air and water from the burning of refuse

During a waste fire, often no waste can be processed by the facility, yet waste is always coming in. This could mean it has to be stored somewhere onsite that's not designed or intended for such storage, which can be dangerous, especially if another fire breaks out. It could mean transporting the waste elsewhere, which creates added costs. In any case, it could lead to service issues for the community. Recycling facilities face more monetary repercussions since they're no longer generating products from the raw materials that come in.

There also may be health and environmental hazards associated with these fires. With plastics burning in many of them, the gases emitted from these fires can force public officials to close businesses and schools - this happened during the recent Connecticut fire. Rivers and other bodies of water could be polluted from the water that runs off of these fires.

[2] https://www.tn.gov/content/dam/tn/health/documents/hc-e-Industrial_Plastics_052714.pdf.

[3] https://www.nfpa.org/News-and-Research/Publications-and-Media/NFPA-Journal/2018/March-April-2018/News-and-Analysis/Dispatches/Waste-Challenge.

APPENDIX 6

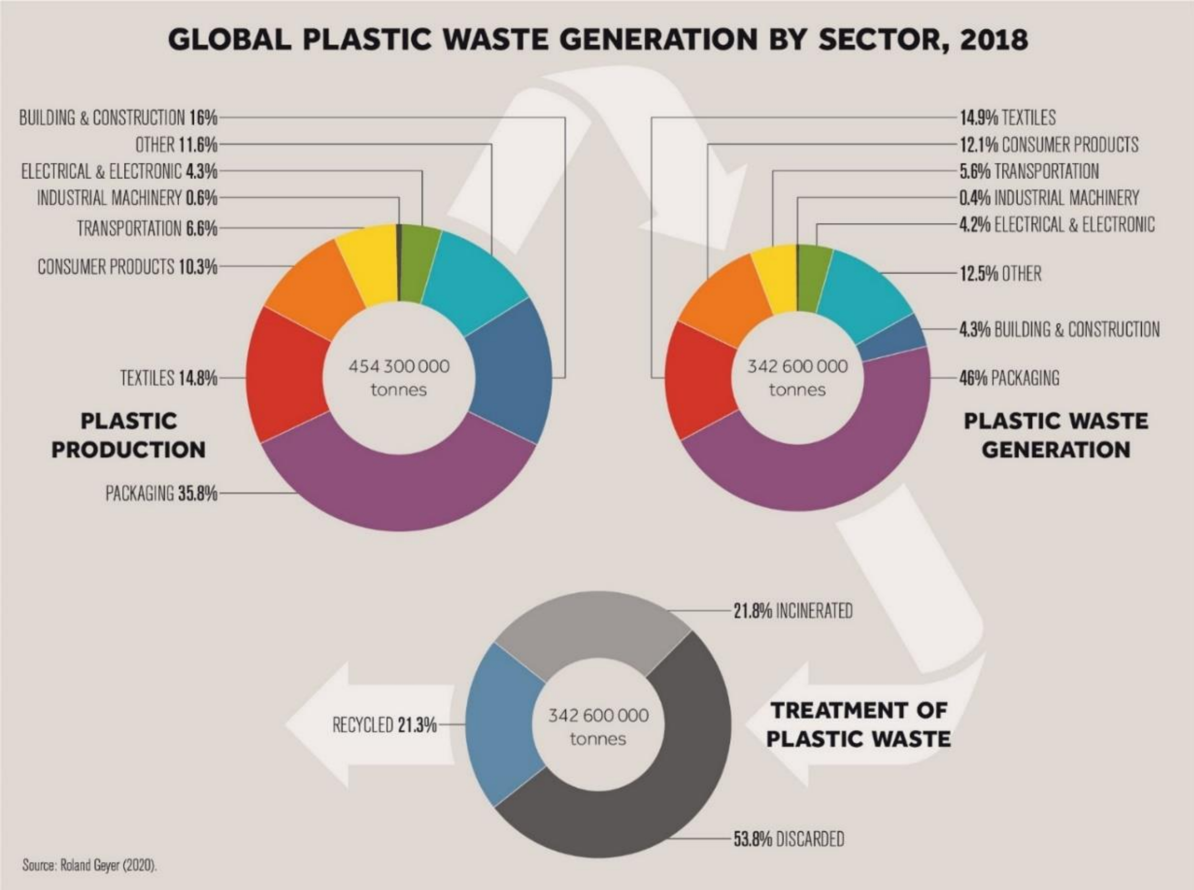
Type and quantity of plastic waste for various processing methods[4]

Origin/waste-generating activity	Type and quantity of waste
Dry blending Banbury mixer	Powder agglomerates, removed by screening drippings, aborted runs
Extrusion compounding	Chunks and strands from extruder purging. Wastes generated during faulty operation (overheating, impure feed). Custom compounding: 1-2% of throughput. In line compounding: 0.2% of throughput.
Injection moulding	Sprues and runners. Normally reground and reprocessed in amounts ranging from 1-15% of total feed. About 1% dirty grindings, floor sweepings, chunk for Purging and contaminated moulding.
Extrusion of pipe, rod, tubing and profiles	2-3% scrap for common extrusion processes. Up to 40-50 % scrap for items machined from rod stock.
Film blowing	Start up, tail and reject film. Extruder purging.
Sheet extrusion	Scrap generation: 15% PE, 25% PVC, 40% PP-film
Extrusion coating	6% loss in extrusion coating on paperboard 5-6% in wire and cable coatings.
Coextrusion	9-10% scrap (sometimes20%) generally sold to convertors
Injection blow moulding	Practically no scrap
Extrusion blow moulding	Amount of pinch-off, depending upon excess length of parsion. Minimized by good design.
Rotational moulding	Removal of open sections, small amounts of trim flash
Dip and slush moulding	No cut-off arises, since the material forms a solid solution on the mould. There is, however, a great potential for contamination of the plastisol or the fluidized solids-bath, resulting in rejected parts
Casting	3-5% loss
Calendering	Drippings from mixer and calender rolls (<1%) Trim, front and strip and tails (6-7%)
Thermoforming	Trimmings arise in significant quantities 8% in high pressure lamination Side trimmings or scrap cuttings when forming labels, bags etc. from laminates
Spreader coating	6-10% scrap, little of which can be recycled
Cellular plastics	5-10% in expanded PS
Compression/transfer moulding	2-5% flash (excess material).

[4] M.Sittig, Pollution Control in the Plastics and Rubber Industry, pp 134-163 (Noyes Data Corp., Park Ridge, N.J. 1975).

APPENDIX 7

Post-consumer plastic waste generation by sector



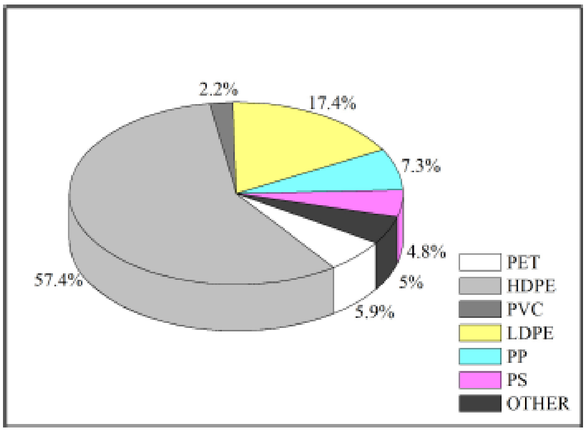
Developed by GRID-Arendal

APPENDIX 8

Composition of plastic waste streams

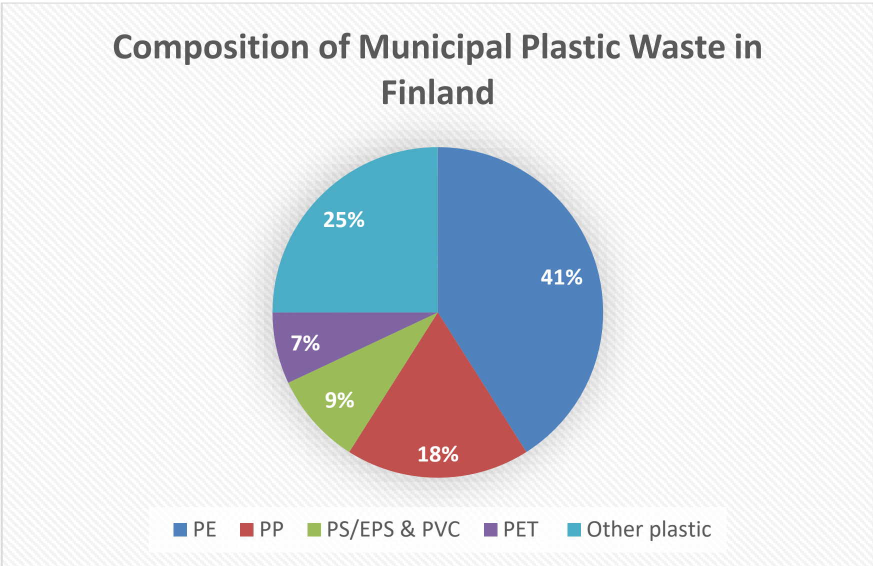
Composition of Municipal Plastic Waste in Bangkok

Major composition of MPW at one of the Bangkok city's waste transfer station observed was HDPE, LDPE, and PP. PET, OTHER, and PS types of plastic showed significant amount as well whereas PVC had the lowest contribution. For the HDPE, it was from plastic shopping and waste bag while the LDPE and PP were from plastic bag and food packaging.[5]



Composition of municipal plastic waste (MPW) by weight.[5]

Composition of Municipa Plastic Waste of Finland



Composition of municipal plastic waste (MPW) by weight[6]

Composition of plastics in Construction and Demolition Waste, Finland

Two diverse waste streams, 86.11 kg of construction and demolition waste (CDW) plastic and 57.74 kg of mechanically sorted plastic, were analyzed by using a handheld tool whose identification technology was based on the near-infrared spectrum. The polymer composition in the plastic waste stream varied depending on the

[5] Chinnathan Areepraserta, Jarudej Asingsamanuntb, Supachot Srisawatb, Jeerattikul Kaharna, Bundit Inseemeesaka, Phatavee Phaseea, Chanoknunt Khaobanga, Wichai Siwakosita, Chart Chiemchaisrib, (2016). Municipal Plastic Waste Composition Study at Transfer Station of Bangkok and Possibility of its Energy Recovery by Pyrolysis. 3rd International Conference on Energy and Environment Research, ICEER 2016, 7-11 September 2016, Barcelona, Spain.

[6] Shehu, S. (2017). Separation of plastic waste from mixed waste: Existing and emerging sorting technologies performance and possibilities of increased recycling rate with Finland as case study.

source, but the most common plastic grades, polypropylene (PP) and polyethylene (PE), were represented in every waste stream.[7]

Plastic polymers, acrylonitrile-butadiene-styrene (ABS), polyamide (PA), polycarbonate (PC), polyethylene (PE), polyethylene terephthalate (PET), polymethyl methacrylate (PMMA), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC) shares (%) in the waste stream. Stream 1 = manually sorted construction and demolition waste (CDW); Stream 2 = mechanically sorted CDW; Stream 2* = mechanically sorted sample.[7]

Stream	ABS	PA	PC	PE	PET	PMMA	PP	PS	PVC	Un [1]/d [2,*]
1	33.91	9.44	0.52	8.44	1.10	0.64	21.45	0.09	9.69	14.71/30.39
2	0.74	-	-	28.42	0.12	-	48.27	5.66	0.05	16.73/49.27
2*	4.91	-	-	6.55	0.32	0.61	53.01	3.73	0.15	30.72/62.00

[1] Unidentified, [2] Dark-colored polymers, * share of dark color material in unidentified material.

Average composition of WEEE plastics:[8] (need to be updated)

HIPS	27%
ABS	24%
PP	5%
PE	2%
HIPS FR	2%
ABS FR	3%
PC-ABS	7%
PPO	3%
POM	1%
PVC	1%
Other Thermoplastics	17%
Elastomers	3%
Parts	2%
Metals	2%
Wood	2%
Other	0%

[7] Lahtela, V., Hyvärinen, M., and Kärki, T., (2019) Composition of Plastic Fractions in Waste Streams: Toward More Efficient Recycling and Utilization.

[8] DSM Environmental Services. (2008). 2007 Massachusetts Construction and Demolition Debris Industry Study. Final report.

APPENDIX 9

Labels bio-based certification

biobased %	*NEN bio-based content* The bio-based label by the Netherlands Standardization Institute (NEN) is based on the European standard EN 16785-1, which enables the independent assessment of claims about the bio-based content of products. The certification system applies to basic materials as well as intermediate and finished products.
BIOBASED > 85 % DIN Geprüft BIOBASED 50 – 85 % DIN Geprüft BIOBASED 20 – 50 % DIN Geprüft	*DIN CERTCO bio-based certification* DIN CERTC's bio-based certification system is based on standard ASTM 6866, CEN/TS 16137 and/or the ISO 16620. The bio-based carbon content in a product is measured using the C method and expressed as a percentage of the total carbon in the product.
between 20 and 40% biobased between 40 and 60% biobased between 60 and 80% biobased more than 80% biobased	*OK biobased* OK biobased is a certification system that verifies the material composition of a product. The Vincotte labelling and certification scheme is based on the C method and measures the bio-based carbon content as a percentage of the total carbon contained in the product/material. This method is backed up by the international standards CEN/TS 16137 and ASTM 6866.
USDA CERTIFIED BIOBASED PRODUCT	*BioPreferred label* The United States Department of Agriculture's certified bio-based product label assures the consumer that a product or package contains a verified amount of renewable biological ingredients. The label is linked to the US standard ASTM 6866, which is the US equivalent of CEN/TS 16137:2011 Plastics – Determination of bio based carbon content