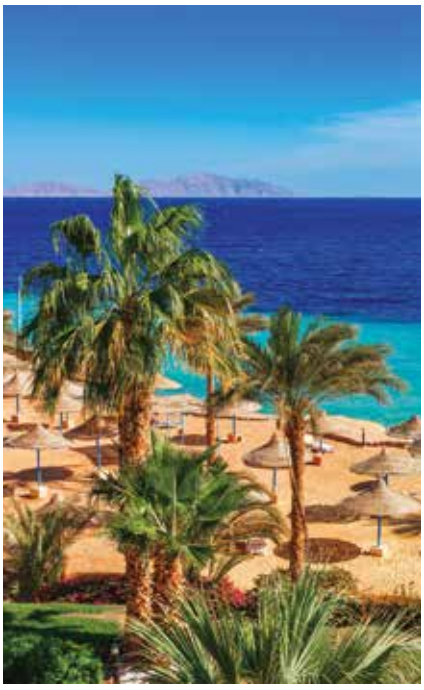


GUIDELINES FOR
HAZARDOUS PLASTIC WASTE
COLLECTION, TRANSPORTATION, TREATMENT AND DISPOSAL



2024

SwitchMed II Project (Policy Component)

to accelerate the implementation of Sustainable Consumption and Production, Circular Economy and Blue Economy

ACKNOWLEDGEMENT

The successful development of the Guidelines for the Collection, Treatment, Transportation, and Disposal of Hazardous Plastic Waste is the culmination of collective effort, expertise, and collaboration. In expressing gratitude, sincere appreciation is extended to all those who have played pivotal roles in this endeavor.

The invaluable contributions of the numerous stakeholders who participated in consultation meetings throughout the guidelines' development have been indispensable.

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SwitchMed is funded by the European Union, coordinated by CEDARE and collaboratively implemented with UNEP and the Ministry of Environment.

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LIST OF ACRONYMS

6PPD	p-Phenylenediamine (N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine)
ABS	Acrylonitrile-butadiene-styrene
AOP	Adverse outcome pathway
BAT	Best available technique
BBP	Benzyl butyl phthalate
BBzP	Butylbenzyl phthalate
BEP	Best environmental practice
BFR	Brominated flame retardant
BHET	Bishydroxyethyl terephthalate
BPA	Bisphenol A
BPB	Bisphenol
CFR	Chlorinated flame retardant
DBDPE	Decabromodiphenylethane
DBP	Dibutyl phthalate
DEHP	Di-2-Ethylhexyl phthalate; Bis(2-ethylhexyl)benzene1,2-dicarboxylate
DIBP	Disobutyl phthalate
DIDP	Diisodecyl phthalate
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester
EC	European Commission
EDCs	Endocrine disrupting chemicals
EPS	Expanded polystyrene
EVA	Ethylene vinyl acetate
HCl	Hydrogen chloride
HF	Hydrogen fluoride
HALS	Hindered amine light stabilizers
HBCDD	Hexabromocyclododecane
HBB	Hexabromobiphenyl
HBBz	Hexabromobenzene
HBM4EU	Human Biomonitoring for Europe
HCB	Hexachlorobenzene
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HDPE	High-density polyethylene

LIST OF ACRONYMS

HFCs	Hydrofluorocarbons
HIPS	High impact polystyrene
IDA	Industrial Development Authority
LCCPs	Long-chain chlorinated paraffins
LDPE	Low-density polyethylene
NIAS	Non-intentionally added substances
OECD	Organisation for Economic Co-operation and Development
OPFRs	Organophosphorous flame retardants
PA	Polyamides
PAHs	Polyaromatic hydrocarbons
PBB	Polybrominated biphenyl
PBDDs	Polybrominated dibenzo-p-dioxins
PBDEs	Polybrominated diphenyl ethers
PBDFs	Polybrominated dibenzofurans
PBT	Persistent, Bioaccumulative, and Toxic
PC	Polycarbonate
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-p-dioxins
PCDFs	Polychlorinated dibenzofurans
PCNs	Polychlorinated naphthalenes
PE	Polyethylene
PEEK	Polyether ether ketone
PES	Polyethersulfone
PFOS	Perfluorooctanesulfonic acid
POPs	Persistent organic pollutants
PP	Polypropylene
PPE	Poly(p-phenylene ether)
PPO	Plastic pyrolysis oil
PS	Polystyrene
PVC	Polyvinyl chloride
VOCs	Volatile organic compounds
VPvB	Very persistent and very bioaccumulative
WMRA	Waste Management Regulatory Authority

PART A:

GENERAL BACKGROUND AND BASIC INFORMATION

1. INTRODUCTION

Plastic waste, especially the hazardous type, is a major global environmental problem with its production drastically increased by more than twenty-folds between 1964 and 2015, with an annual output of 322 million metric tons, which is expected to double by 2035 and quadruple by 2050 if no action is taken. The mismanaged plastic waste mostly originating from land, is not only contaminating the land but released to marine environment, polluting it and threatening biodiversity while also negatively impacting the blue economy.

The problem of marine plastic litter can be addressed through implementing circular economy practices. Circular economy practices, inter alia, necessitate policy frameworks to create incentives for economic actors, such as industry as well as consumers, to increase the productivity of resources used. This is realized by maintaining the value of the product and its materials at any point of its life cycle and avoiding premature discarding of products and/or their materials, which includes plastics. Circular economy, in conjunction with optimizing landfill management, will help to substantially reduce the amount of those plastics that are most likely to end up as marine plastic litter.

When assessing the quality of recycled plastics, factors such as material purity, mechanical properties, chemical composition, and potential contaminants are considered. Testing methods, such as spectroscopy, thermal analysis, and mechanical testing, are often employed to evaluate the quality and performance of recycled plastic materials. There are some commonly recognized standards and guidelines that can be used to assess the quality of recycled plastic materials such as:

- International Organization for Standardization (ISO): ISO has developed standards related to recycled plastics. ISO 15270 provides guidance on the recycling of plastics waste, including quality management systems and general principles for designating plastics for recycling.
- Association of Plastic Recyclers (APR): The APR has developed guidelines for post-consumer resin (PCR) used in plastic products. These guidelines include specifications for various types of plastics, such as PET (polyethylene terephthalate), HDPE (high-density polyethylene), and PP (polypropylene), and provide recommendations for purity, physical properties, and processing conditions.

- ASTM International: ASTM has several standards related to recycled plastics. For example, ASTM D5033 provides guidelines for determining the compatibility of recycled plastics with different polymer materials, while ASTM D7611 establishes specifications for selecting plastics suitable for recycling into building and construction products.

Thus, it is crucial to promote environmentally sound approaches through proper guidelines along the whole life cycle of the plastic, especially the hazardous fractions and types of such waste, in order to minimize the hazard associated with its total management process including collection, transportation, storage and its final fate of safe disposal.

The current document is based on a previous report (Report 1), which classified all types of plastic in accordance with their hazard. This document is divided into two parts:

- Part 1 includes general background and basic information about the regulations that govern the management of the hazardous waste in general, the hazard and health risk associated with plastic, estimation of quantities of plastic waste in Egypt, as well as the needs for the guidelines.
- Part 2 includes detailed guidelines for the environmentally sound transportation, segregation, transportation, storage and final safe disposal of the hazardous plastic waste.

2. OBJECTIVE AND SCOPE OF GUIDELINES

The objective of these guidelines is to provide support to the competent authorities of Egypt, especially the Waste Management Regulatory Authority (WMRA), to establish a regulatory system for the environmentally sound management of hazardous plastic waste including its collection, transportation, storage and final disposal/recycling. All obligations of these guidelines shall be in accordance with the laws and the rules applicable on both national and internal levels.

WMRA shall be responsible for the implementation of these guidelines through periodical audits executed by its staff or by an appointed competent third-party agency; compliance shall be documented and certified by WMRA.

3. REGULATORY FRAMEWORK

This section presents a review for national and international legislations governing hazardous waste management in particular.

3.1 National Legislations

The national legislations governing the waste management in general, and the hazardous waste in particular are the following:

- Law 202/2020 for Waste Management:
  Law 202/2020 seeks to promote waste recycling and reuse by focusing on the integrated management of municipal, industrial, agricultural, demolition and construction waste, in addition to their safe disposal. Main goals of the Law are:
  - Develop an integrated management of municipal, industrial, agricultural, demolition and construction waste as well as their safe disposal.
  - Reduce waste generation.
  - Promote reuse.
  - Work to ensure the recycling, treatment and final disposal of waste.
  - Manage waste in a way that reduces damage to public health and the environment.

A Waste Management Authority is established at article 3 with the following tasks:

- Regulating, tracking, auditing, evaluating and developing everything related to Integrated waste management activities.
- Attracting investments in the field of integrated waste management activities to ensure sustainable development.
- Following up the implementation of the plans required to regulate waste management in cooperation with governmental institutions, municipal governments, the private sector, NGOs and international organizations.
- Issuing the licenses needed to undertake waste management activities.

Regarding plastic waste, the following are provided:

- Single-use plastic bags measures include:
  - Their manufacture, import or export shall be in accordance with the technical controls, requirements and specifications issued by a decision issued by the Minister of Trade and Industry, including their ban in case of components with inputs or materials that seriously harm the environment.
  - Their sale, circulation, storage, free distribution, or disposal may take place only in accordance with the controls, conditions and technical specifications determined by the executive regulations of this Law.
  - Issuance of a system of financial and economic incentives and tax and customs exemptions to encourage the import, production and manufacture of safe, environmentally friendly alternatives for single-use plastic bags (art.27).
- It established a sanitation fund in each governorate or new urban communities' apparatus for the collection services of municipal waste (art.35).
- The law classifies waste as (a) hazardous or (b) non-hazardous. The requirements for the management of each are as follows (a): (i) obtaining a special license for the integrated management of hazardous waste and substances; (ii) obtaining an approval from the Waste Management Authority for its circulation; (iii) maintaining a register of such waste and the methods of disposal; and (iv) sterilizing and disinfecting the place where the facility producing such waste was established in case it was moved or its activities suspended; (b): (i) obtaining a license for the integrated management of non-hazardous waste; and (ii) taking all precautions required to avoid causing any harm to the environment.

Environmental Laws

- Environmental Impact Assessment (EIA) Requirements: Articles 19, 20, 21 and 23 of law 9/2009 (Law 4/1994 and 9/2009 and their amendments and executive regulations).
- Environmental Register Requirements: Article 22 (Law 4/1994 and 9/2009 and their amendments and executive regulations).
- Workplace Requirements: Article 43 (Law 4/1994 and 9/2009 and their amendments and executive regulations).
- Hazardous Waste Storage Requirements: Article 28/1 (executive regulation of Law 4/1994 and 9/2009 and its amendments and executive regulations).
- Article 28/3 (executive regulation): the article regulates the transportation of hazardous waste.
- Articles 29, 30, 31 of the law 4/1994 and 9/2009 and its amendments and executive regulations, and articles 25,26 and 27 of the executive regulations regarding the Ministry of Trade and Industry regulation for hazardous waste storage and transport.

3.2 International Conventions

The Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted on 22 March 1989 and entered into force on 5 May 1992. The Basel Convention emphasizes, amongst other principles, environmentally sound management of hazardous wastes, which is defined as taking all practicable steps to ensure that hazardous wastes are managed in a manner which will protect human health and the environment against the adverse effects resulting from such wastes. The Convention stipulates a number of specific objectives, including the following:

- The reduction of transboundary movements of hazardous and other wastes
- The prevention and minimization of the generation of hazardous wastes
- The active promotion of the transfer and use of cleaner technologies

Annex VIII[1] of the Basel Convention (A1, A2, A3 and A4) refers to e-waste, which is considered hazardous under Art. 1, par. 1(a) of the Convention: Waste of electrical and electronic assemblies[2] or scrap containing components such as accumulators and other batteries, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with cadmium, mercury, lead, polychlorinated biphenyl to an extent that they possess any of the characteristics contained in Annex III of the Basel Convention.

The Stockholm Convention

The Stockholm Convention prohibits the production and use of the POPs listed in the Convention and restricts their trade across international boundaries. However, the Convention contains exceptions to these general rules and allows for limited and carefully controlled uses of certain POPs for which safer alternatives do not exist or are not readily available to all countries.

The pillars of the Stockholm Convention are:

- Eliminating or reducing the production and use of the intentionally produced POPs listed in Annexes A and B of the convention;
- Minimizing and where feasible eliminating releases of unintentionally produced POPs listed in Annex C of the convention;
- Cleaning-up of old stockpiles and equipment containing POPs;
- Supporting the transition to safer alternatives;
- Targeting additional POPs for action.

(1) Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

(2) Draft Technical Guidelines on Transboundary Movement of E-Waste, In Particular Regarding the Distinction Between Waste and Non-Waste, Draft for consultation (Version 22 September 2010).

3.3 International Legislations: EU Directive

The objective of the EU Directive (2002/96/EC of the European Parliament[3]) is to preserve, protect and improve the quality of the environment, protect human health and utilize natural resources prudently and rationally. This policy is based on the precautionary principle which requires that preventive action should be taken in order to rectify any damage to the environment at source. The Directive introduced the "Polluter Pays Principle" and the "Extended Producer Responsibility (EPR)" and included recycling and recovery targets for certain waste streams.

Regarding plastic waste, the Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. This Directive promotes circular approaches that give priority to sustainable and non-toxic reusable products and reuse systems rather than to single-use[4].

4. PLASTIC WASTE HAZARD

4.1 Degradation of Plastic Products

Generally, natural degradation of plastic occurs through four mechanisms by which plastics decompose in the environment:

4.1.1 Photo degradation

The sun's rays have capabilities in its ultraviolet light (UV light) and infrared radiation which bring about the incorporation of oxygen molecules into the plastic, a process known as oxidation. As more and more oxygen intermingles with the polymer in the plastic, it becomes brittle and easier to break into ever diminishing pieces.

Eventually, the pieces of plastic will become small enough to be consumed by microorganisms, which are able to metabolize it and convert it to carbon dioxide (CO_2) or absorb it into their own biomolecules.

On the whole, this is an incredibly lengthy process, often taking as much as 50 years or more for the sun to completely break down the plastic and for the microbes to assimilate the polymer molecules. This process becomes even more arduous and protracted when it takes place underwater. Because of the negligible rate of hydrolysis of most plastics in the ocean and of the lower temperatures, sunlight exposure and oxygen availability in seawater, the whole thing can take significantly longer.

(3) DIRECTIVE 2012/19/EU of The European Parliament and of The Council of 4 July 2012 on waste electrical and electronic equipment (WEEE).
(4) DIRECTIVE (EU) 2019/904 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

Because of these reasons, people often turn to alternative methods of plastic disposal, such as landfill sites or incineration facilities. However, neither of these alternatives are very eco-friendly nor efficient. While recycling plastic is a more favorable alternative, it too is not a cost-effective option and has an unimpressive rate of efficiency.

4.1.2 Thermos oxidative degradation

Oxidative degradation is usually initiated when polymer chains form radicals, either by hydrogen abstraction or by homolytic scission of a carbon-carbon bond. This can occur during manufacture, processing or during service when exposing the polymer to light or heat.

4.1.3 Hydrolytic degradation

In hydrolytic degradation, polymer bonds react with water molecules, break up, and produce new chain ends. The original chains break up into smaller segments, resulting in polymer degradation. Most chemical groups that react with water contain O, N, S, P, and other non-carbon atoms.

4.1.4 Biodegradation by microorganisms

Biodegradation of plastics involves excretion of extracellular enzymes by the microorganism, attachment of enzyme to the surface of plastic, hydrolysis to short polymer intermediates, which are ultimately assimilated by microbial cells as carbon source to release CO_2.

Natural degradation of plastic begins with photo degradation, which leads to thermos oxidative degradation. Ultraviolet light from the sun provides the activation energy required to initiate the incorporation of oxygen atoms into the polymer[5]. This causes the plastic to become brittle and to break into smaller and smaller pieces, until the polymer chains reach sufficiently low molecular weight to be metabolized by microorganisms. These microbes either convert the carbon in the polymer chains to carbon dioxide or incorporate it into biomolecules.

4.2 Leaching of Hazardous Elements Included in Plastic Product

Release of the additives to the surrounding environment has a negative effect on the product properties and on the environment, since loss of additives shortens polymer lifetime, e.g., loss of plasticizers lowers the tensile strength of polyvinyl chloride PVC[6]; and living organisms are exposed to the released additives. Phthalates, organotin and Bisphenol A, have been shown to target nuclear hormone receptor[7]. The release may take place during the service life of the plastics or after their disposal in landfills. Both the landfill compartment and other potential receptors such as sediments represent complex environments with multiple chemical and biological processes occurring concurrently.

(5) Andrady, A.L. Micro plastics in the marine environment. Mar. Pollut. Bull. 2011, 62, 1596–1605. [Google Scholar].

(6) Boyer R. F.1951Relation of tensile strength to brittle temperature in plasticized polymers. J. Appl. Phys. 12, 723–728 [Google Scholar].

(7) Grun F., Blumberg B.2007Perturbed nuclear receptor signaling by environmental obesogens as emerging factors in the obesity crisis. Rev. Endocr. Metab. Disord. 8, 161–171 (doi:10.1007/s11154-007-9049-x) [PubMed] [Google Scholar].

4.3 Emissions of Hazardous Elements during Burning

Incineration of plastic waste in an open field or landfills is a major source of toxic air pollutants such as Dioxins, Furans (persistent organic pollutants -POPS), Mercury and Polychlorinated Biphenyls into the atmosphere. Further, burning of Poly Vinyl Chloride liberates hazardous halogens and pollutes air, the impact of which is climate change.

The toxic substances thus released are posing a threat to vegetation, human and animal health and environment as a whole. The hazardous brominated compounds act as carcinogens and mutagens, while Dioxins settle on the crops and in waterways where they eventually enter into the food chain and hence the body system.

These Dioxins are the lethal persistent organic pollutants (POPs) and its worst component, tetrachlorodibenzo-p-dioxin (TCDD), commonly known as agent orange is a toxic compound which causes cancer and neurological damage, disrupts reproductive thyroid and respiratory systems, initiate risk of heart disease, aggravates respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches, and damages the nervous system.

5. ESTIMATION OF PLASTIC WASTE GENERATION IN EGYPT

5.1 Estimation of annually generated plastic waste from local products in Egypt

Plastic waste occupies rank number 3 in terms of quantity of waste generated in Egypt[8]. The last updated data obtained from IDA for plastic annual production was used to estimate the generated quantity of plastic waste per year. It is assumed that 100 % of products are transferred to waste. The following Table shows the quantity of each type.

PLASTIC TYPE	QUANTITY (TONS)	PERCENTAGE
PET	1,390,898	11.8
HDPE	5,845,585	49.6
PVC	2,127,151	18
LDPE	1,021,987	8.7
PP	379,929	3.2
PS	747,335	6.3
Others	277,042	2.4

Table 1: Estimated quantities of plastic waste generated of all types.

(8) Zaki, T., & Khayal, A. (2010). Country report on the solid waste management in Egypt. The regional solid waste exchange of the information expertise network in Mashreq and Maghreb Countries.

The Table shows that HDPE is the most prevalent plastic waste type, accounting for 49.6% of the total amount of generated waste. The second highest percentage is attributed to PVC waste at 18%. PET waste represents 11.8%. LDPE and PS represent 8.7% and 6.3% respectively.

The next Figure shows the distribution of each type of waste.

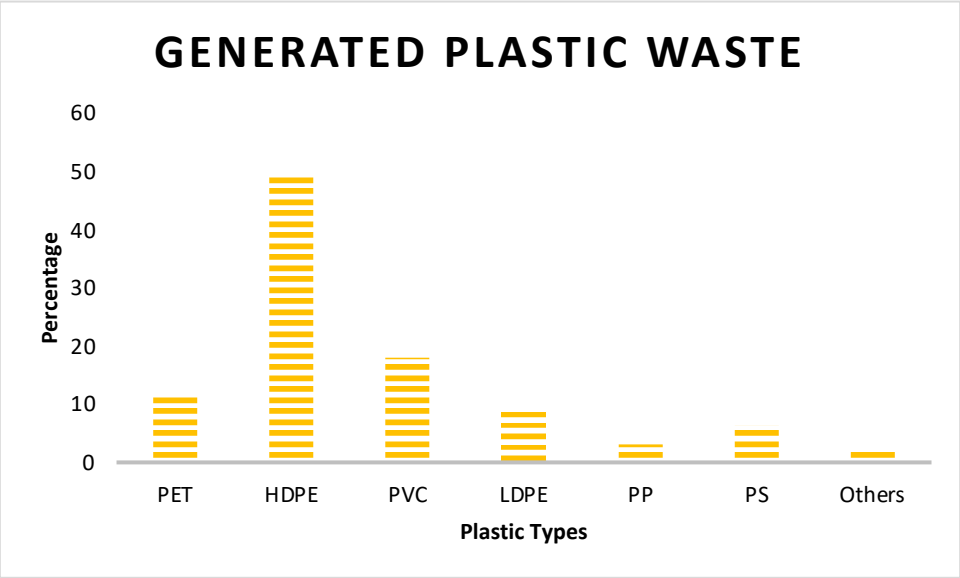


Figure 1: Generated plastic waste.

5.2 Estimation of annually generated plastic waste containing BFR

In reference to (Assessment of the Problematic Fractions) report published in 2022[9], the following was concluded.

Amount of electronic equipment containing problematic fractions in Egypt up to 2022.

(9) F. Soliman, 'Assessment of the Problematic Fractions', Sustainable Recycling Industries (SRI), CEDARE, 2022.

EQUIPMENT CLASSIFICATION FOLLOWING ITS HAZARDOUS MATERIAL CONTENT	HAZARDOUS MATERIAL CONTENT	REMARKS
CRT Panel Display	• Lead • Cadmium • Mercury • PCDD (UPOP)	• However discontinued production: it is still stocked in the market as waste (147,000 tons). • Contain high level of Hazardous materials
Desktop	• PBDE • PBDD (UPOP) • PCDD (UPOP)	• Around 350,000 ton Stocked in the market as waste
LCD	• Mercury • PBDE • PBDD (UPOP) • PCDD (UPOP)	• Around 117,000 ton stocked in the market as waste
Laptop	• Mercury • PBDE • PBDD (UPOP) • PCDD (UPOP)	• Around 99,000 ton stocked in the market as waste
UPS – Un-interruptible Power Supply	• Lead	• No information is available in the market despite its hazardous contents.

Table 2: Quantity of equipment containing hazardous materials (problematic fractions) in Egypt up to 2022.

As shown from the previous table, all equipment contains hazardous, and fire-retardant materials.
The evaluation of the amount of problematic fractions/percentage of plastic containing BFR is shown in the next Table.

EQUIPMENT	PERCENTAGE OF PLASTIC CONTAINING BFR
CRT Panel Display	21-23%[10],[11],[12]
Desktop	30-40%[13]
LCD	About 40%[14]
Laptop	33%[15]
Mobile Smart Phone	30%[16]
UPS – Un-Interruptible Power Supply	60-80%[17]

Table 3: Content of BFR containing plastic in electronic equipment.

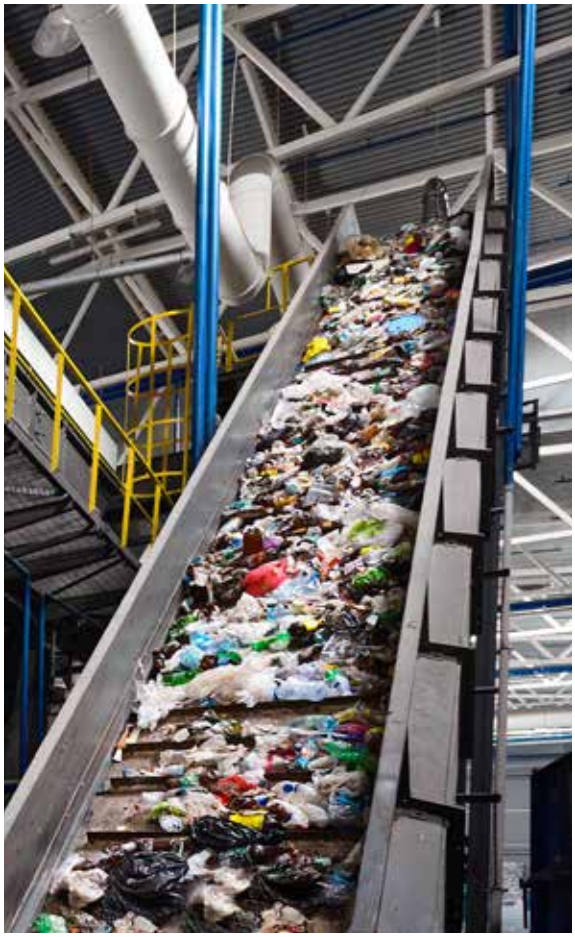
(10) Peeters, J. R., Vanegas, P., Kellens, K., Wang, F., Huisman, J., Dewulf, W., & Duflou, J. R. (2015). Forecasting waste compositions: A case study on plastic waste of electronic display housings. Waste management, 46, 28-39.
(11) Huisman, J., Ansems, T., Feenstra, L., Stevels, A., 2001. The QWERTY concept, a powerful concept for evaluating the environmental consequences of end-of-life processing of consumer electronic products. In: Proceedings EcoDesign 2001: Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 2001, pp. 929–934.
(12) Berkhout, F., Hertin, J., 2004. De-materialising and re-materialising: digital technologies and the environment. Futures 36, 903–920.
(13) https://globalowls.com/negative-impact-computer-plastic-on-environment/#
(14) https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Substance_Review/Substance_Profiles/20140404__Antimony_EFRA_2013.pdf
(15) Ekener-Petersen, E., & Finnveden, G. (2013). Potential hotspots identified by social LCA—part 1: a case study of a laptop computer. The International Journal of Life Cycle Assessment, 18, 127-143.
(16) https://www.statista.com/statistics/270454/top-10-materials-in-a-smartphone/
(17) https://www.n1critical.com/how-to-recycle-your-old-ups-and-its-lead-acid-batteries/

From the previous two Tables, the amount of problematic plastic fractions in electronic equipment, especially the ones that contain flame retardant materials, could be calculated.

6. EFFORTS TO ESTABLISH WASTE MANAGEMENT GUIDELINES

Efforts to establish waste management guidelines in Egypt are ongoing to address the country's growing waste management challenges. Here are some key initiatives and efforts that have been undertaken:

1. National Solid Waste Management Program: The Egyptian government launched the National Solid Waste Management Program in 2011. The program aims to improve waste collection, transportation, and disposal systems across the country. It includes the development of infrastructure, such as waste treatment plants and sanitary landfills, and the promotion of sustainable waste management practices. The program made number of contributions such as:



- Guidelines for Closure of Municipal Solid Waste Dumpsites.
- EPR Scheme for Packaging Waste in Egypt.
- Agricultural Residue Management Strategy.
- Construction & Demolition Waste Technical Guidelines.

2. Integrated Resource Recovery Centers (IRRCs): The Ministry of Environment in Egypt has been implementing the IRRCs project since 2014. These centers aim to promote waste recycling and recovery by establishing facilities that sort, separate, and process different types of waste. The project focuses on recovering recyclable materials and generating energy from organic waste.
3. Legal and Regulatory Framework: Egypt has been working on strengthening its legal and regulatory framework for waste management. The government has introduced laws and regulations to enforce waste segregation, recycling, and environmentally sound waste disposal practices. This includes imposing fines and penalties for improper waste handling.

4. International Cooperation and Support: Egypt has sought international cooperation and support to develop its waste management sector. It collaborated with international organizations, such as the United Nations Environment Programme (UNEP) and the European Union, to access funding, technical expertise, and best practices in waste management.

These efforts demonstrate Egypt's commitment to improve waste management practices and addressing environmental concerns. While progress has been made, there is yet a need for continued investment, public participation, and the implementation of comprehensive waste management guidelines to achieve sustainable waste management in the country.

7. BENEFICIARIES

These guidelines shall be used by all those who handle hazardous plastic waste, which includes the collectors, transporters, stores keepers, and disposal facility management irrespective of their scale of operation. The definitions of people or entities dealing with hazardous plastic waste include:

7.1 Regulatory Authorities and Agencies

- Hazardous Waste Management Department at the Waste Management Regulatory Agency (WMRA) of the Ministry of Environment (MoE)
- Central Inspection Department of EEAA
- Regional Bureau Offices (RBOs) belonging to the Governorates
- Central Administration for Environmental Impact Assessment in EEAA
- Waste Management Authority at the Ministry of Local Development
- Plastics Industry Chamber
- Food Safety Authority
- Egyptian Standardization Authority
- The Occupational Health and Safety Authority

7.2 Worker in the Plastic Recycling

- Management of Formal Entity (factory or premises) that receives, handles, processes and recycles plastic waste.

- Operators who operate a facility for collection, reception, classification, treatment, storage or disposal of such hazardous waste.
- Recyclers who procure and process hazardous materials for recovery.
- Recyclers working in reclamation and reprocessing of hazardous materials from a production process in an environmentally sound manner for the original purpose or for other purposes.
- Transporters working in the transportation of hazardous plastic waste at all levels.

8. NEED FOR THE GUIDELINES FOR ENVIRONMENTALLY SOUND MANAGEMENT

Based on the outcomes of many efforts exerted lately in the domain of hazardous waste management in Egypt, and the consensus reached with many stakeholders such as the Ministry of Environment, the Ministry of Local Development, WMRA and EEAA, the Guidelines for the Environmentally Sound Management of hazardous plastic waste was mandatory. These guidelines shall provide the minimum practice required to be followed in the management chain of hazardous plastic waste to control adverse effects on the environment or the people working in the field, and to allow the Government to take stringent norms as deemed necessary. The guidelines are necessary due to the following reasons:

8.1 Current Status of Hazardous Plastic Waste Management in Egypt

The hazardous plastic waste management sector faces many challenges such as:

- The legal constraint, as currently no laws exist or are being developed in Egypt addressing such waste management.
- The organizational issue, as the whole management chain of that type of waste is currently performed in a haphazard way.
- The dominance of the informal sector, which controls the waste business in Egypt, is manipulating the collection, transportation, storage, recycling and final disposal of such waste. This sector is acting with no regulations or environmental control.

It is worse noting that WMRA is exerting continuous efforts toward organizing this sector and transforming all informal facilities to formal in order to boost the performance of this sector.

8.2 Environmentally Sound Incineration Facilities

In the absence of environmentally sound incineration facilities, this type of waste finds its way to many channels of uncontrolled practices such as inappropriate recycling, open burning, dumping in landfills, etc.

Recently, the cement kilns received the plastic waste as alternative fuel. The incineration in the cement needs specific arrangement starting from receiving the waste in proper receiving area, internal handling up to the burning facility, and treatment of emitted gas waste streams through a-state-of-the-art wet scrubbers to wash-out the Dioxin and Furan evolving in the waste stream.

Apart from the incineration in cement kilns, no dedicated facilities exist in Egypt to incinerate hazardous plastic waste especially that contains Brominated and chlorinated fire retarding elements such as included in the electronic waste fractions and non-recyclable plastic (PVC and PC) causing the emission of Un-intentional POPs such as dioxin and furan. Moreover, the uncontrolled management of such fractions leaves behind emissions containing PBDEs (Poly-brominated Diphenyl Ethers), which are persistent, toxic chemicals that spread in the environment for long time and distances causing many adverse effects to human health and the environment.

9. HEALTH RISK OF PLASTIC WASTE

The plastic waste induced health risks may result from direct contact with harmful materials such as lead, cadmium, chromium, BFRs or polychlorinated biphenyls (PCBs), from inhalation of toxic fumes, as well as from accumulation of chemicals in soil, water and food. Hazards can occur during the waste recycling and as a result of improper disposal.

Unfortunately, this waste recycling is often done by workers with little or no training, safety gear, equipment, or proper facilities.

This section presents a review for health risks associated with the exposure to heavy metals, POPs, and UPOPs.

9.1 Exposure to Hazardous Substances

Many hazardous substances are included in plastic waste such as:

- 1,1-Dichloroethylene
- 1,4-Dichlorobenzene
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- 2,4-Dinitrotoluene
- Antimony Oxide
- Arsenic
- BAPs
- Barium
- Benzene
- Bisphenol A & 5 (BPA & BP5)
- Bromine
- Cadmium
- Carbon tetrachloride
- Chlordane
- Chlorobenzene
- Chloroform
- Chromium
- Cresol
- Diazomethane
- Endrin
- Ethylene Oxide
- Heptachlor (and its epoxide)
- Hexachlorobenzene
- Hexachlorobutadiene
- Hexachloroethane
- Lead
- Lead Oxide
- Lindane
- m-Cresol
- Mercury
- Methoxychlor
- Methyl ethyl ketone
- Nitrobenzene
- o-Cresol
- p-Cresol
- Pentrachlorophenol
- Phthalates
- Pyridine
- Selenium
- Silver
- Tetrachloroethylene
- Toxaphene
- Trichloroethylene

These substances have the greatest potential to cause harm on account of their existence in many plastic wastes. The toxicity of some of their combined or elemental forms, and their widespread distribution in the environment aggravate this harm.

9.2 Exposure to POPs

Primitive recycling techniques, such as open burning of non-recyclable waste, expose both adult and child workers to a range of hazardous substances. The induced health risks may result from direct contact with harmful substances such as BFRs or PCBs from the inhalation of toxic fumes, as well as from accumulation of chemicals in soil, water and food. In addition, while being processed, the burning of non-recyclable waste can give rise to a number of toxic by-products (un-intentional POPs – Dioxin and Furan) likely to affect human health.

One of the major goals of the Stockholm Convention is the continuing minimization and, where feasible, ultimate elimination of unintentionally produced POPs listed in Annex C, Part I of the convention. The list includes the chlorinated/brominated compound releases of unintentional POPs derived from anthropogenic sources such as Chlorinated and Brominated Compounds.

9.3 Exposure to UPOPs

The release of UPOPs may happen during controlled burning (in furnaces) or as a result of open burning.

Controlled Burning of Chlorinated Compounds

- Polychlorinated dibenzo-p-dioxins (PCDD) and Polychlorinated dibenzofurans (PCDF) PCDD emissions from controlled combustion sources containing chlorine can be explained by three principal mechanisms, which should not be regarded as being mutually exclusive:

  - The first is that PCDDs and PCDFs are present as contaminants in the combusted organic material and pass through the burning process and are emitted unaltered at the end through the furnace stack. The incomplete destruction of PCDD/PCDF helps in the release of such compounds, where the molecules are partially destroyed during this combustion allowing trace amounts to be released (100 ppt to 1 ppb).
  - The second mechanism encompasses the formation of PCDDs and PCDFs from aromatic precursor compounds in the presence of a chlorine donor. The general reaction in this formation is an interaction between an aromatic precursor compound and chlorine.

Examples of precursor compounds include chlorobenzenes, chlorophenols, phenol, and benzene (flame retardants). Examples of diverse chlorine donor compounds are polyvinyl chloride (PVC), and gaseous hydrogen chloride (HCl). In the post-combustion region outside the furnace, heterogeneous reactions proceed to form CDD/CDFs. Temperature of the combustion gases is, perhaps, the most dominant factor in the formation of CDDs and CDFs from aromatic precursor compounds. It was found that formation probably occurs outside the combustion zone of a furnace in regions where the temperature of the combustion of gases has cooled within a range of 200° to 450°C.

- The third last mechanism is de novo synthesis, which promotes CDD/CDF formation in combustion processes from the oxidation of carbon particulate catalyzed by a transition metal in the presence of chlorine. As in the second mechanism, synthesis is believed to occur in regions outside of the furnace zone of the combustion process, where the combustion gases have cooled to a range of temperatures considered favorable to formation chemistry. A key component to do novo synthesis is the production of intermediate compounds (either halogenated or non-halogenated) that are precursors to CDD/CDF formation.

- Polychlorinated biphenyls (PCBs) are chlorinated compounds found mainly in the capacitors that exist in the Printed Circuit Boards as well as in the old transformers oil. Probably the formation mechanisms that apply to CDDs/CDFs would also apply to PCBs. The above mentioned first mechanism is applied. This may indicate that PCBs present in the material fed into an incineration process may result in PCB emissions from the stack of the process.

During Controlled Burning of Brominated Compounds:

- Poly-brominated dibenzodioxins and dibenzofurans (PBDD/Fs) are compounds released from Poly-brominated diphenyl ethers PBDE and Hexa-bromo-biphenyl (HBB) as PCDD and PCDF like structure. The main use for PBDE is as flame retardants in consumer products as well as packaging and solid elastomers; their major stocks are predicted to be in polyurethane (flexible) foams. Release of PBDD/Fs from treated products into the environment are from recycled BFR containing materials. The formation and release of such compounds from the incineration of waste that contain brominated flame retardants (BFRs) are a concern.
- Poly-brominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs) occur as trace (ppb) contaminants in brominated flame retardants and are produced during combustion of these chemicals (Mechanism 1 – previously described). They are also formed when organics are incinerated in the presence of bromine. Moreover, combustion of organics in the presence of both bromine and chlorine results in the formation of mixed (i.e., bromo, bromo/chloro and chloro) halogenated dibenzodioxins and dibenzofurans (HDDs and HDFs). The biological effects of PBDDs and PBDFs are similar, if not identical, to those of PCDDs and PCDFs.

Steps of Dioxin/ Furan Formation and Temperature Effect:

The incineration process takes place inside the furnace starting from 1200 °C and declines until 400 then 250 °C (range of chemical reaction initiation) where UPOPs formation takes place. The maximum formation occurs at 350 °C[18] . Retention time also plays a role in the UPOPs formation during incineration or burning.

(18) Retrieved from: https://cfpub.epa.gov/ncea/iris_drafts/dioxin/nas-review/pdfs/part1_vol1/dioxin_pt1_vol1_ch02_dec2003.pdf, Mechanisms of Formation of Dioxin-Like Compounds During Combustion of Organic Materials

One of the solutions to avoid the UPOPs formation is the rapid quenching of the flue gases emitted at 1200 ° C to less than 100 ° C. This destroys UPOPs completely and passes the gases into a multi-stage scrubber to wash the quenching water.

Role of Chlorine:
HCl vapor is the dominant source of chlorine leading to the formation of CDD/CDFs. The reaction proceeds via the oxidation of HCl in the presence of an inorganic chloride catalyst as shown in the next steps.

First Step:
The initial step in forming dioxin is the formation of chlorine from HCl in the presence of oxygen:

$$2HCl + \tfrac{1}{2} O_2 \longrightarrow H_2O + Cl_2$$

Second Step:

Phenol + Cl2 ⟶ Chlorophenol (dioxin precursor)

Third Step:

Happens at a Temperature between 200-450 C ° – Suitable to Enhance Chemical Reaction Catalyst

As previously demonstrated, the formation probably occurs outside the combustion zone of a furnace in regions where the temperature of the combustion of gases has cooled within a range of 200° to 450°C.

Brominated UPOPs are released following the same procedure detailed above with the existence of bromine.

Uncontrolled Burning

Open burning is an environmentally unacceptable process that generates numerous pollutants. It is a serious threat to public health and the environment.

The typical low temperature burning, and smouldering conditions of open burning promote the formation of many toxic and potentially harmful chemicals, including chemicals listed in Annex C of the Stockholm Convention. These compounds may form during open burning regardless of the composition of the material being burnt. The compounds produced from open burning can travel long distances and deposit on soil, plants, and in water. Typical practice especially by the informal sector of open burning is the copper extraction from plastic coated electric wires (PVC coated wires) and cables, also the burning of plastic and foam containing fire retarding materials.

The following conditions are associated with the uncontrolled burning of waste enhancing the evolvement of UPOPs:

- Temperature is uncontrolled.
- Open air burning temperature is suitable for chemical reaction resulting in UPOPs especially when waste loads contain high chlorine and/or bromine content, such as PVC and/or BFR.
- PC/BDD/Fs are POPs produced due to incomplete combustion of waste during open burning or poor incineration at low temperatures. They are prevalent in places where plastics are burned. For instance, the burning of insulated wire has been found to produce 100 times as many dioxins as the burning of domestic waste[19].
- Incomplete combustion that occurs in O_2 deprived conditions and at lower temperatures, exactly the conditions involved in uncontrolled open burning that produces POPs such as polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), polychlorinated biphenyls (PCB) and hexa-chloro-benzene (HCB) as products of incomplete combustion.
- Polychlorinated dibenzodioxins/furans (PCDD/Fs), poly-brominated dibenzodioxins /furans (PBDD/Fs), polychlorinated biphenyls (PCBs) and other dioxin-like compounds are emissions that are associated with open burning of waste and poor waste management practices in general.

(19) "Exposure to Dioxin and Dioxin-like Substances: A Major Public Health Concern", World Health Organization, Geneva, Switzerland,

PART B:

GUIDELINES FOR HAZARDOUS PLASTIC WASTE COLLECTION TRANSPORT, STORAGE AND SAFE DISPOSAL

10. GENERAL PRINCIPLES

The guidelines should be considered mandatory with respect to every undertaking operating in the field of segregation, sorting, treatment storage and disposal of plastic waste. The Guidelines are non-exhaustive for all processes where emissions of hazardous substances occur.

For such treatment, specific process and management standards shall be applied. In addition, compliance with the regulatory requirements is verified by regular audits executed by the WMRA or by a competent third party. Compliant undertakings will be issued with an audit certificate, and in accordance with the following.

- The recycling, and disposal facilities shall ensure that there is insurance cover according to standards of health and financial compensation.
- The recycling and disposal facilities shall undertake Environmental Social Impact Assessment (ESIA) as required by laws.
- The requirements described in the guidelines must hold for every operator.
- Presence of civil defense (firefighting) services in the facility

In the following sections a full description of the required guidelines is provided for the segregation, sorting, treatment and storage, and final safe disposal of hazardous plastic waste.

11. PERSONAL PROTECTION EQUIPMENT FOR HAZARDOUS WASTE HANDLING

Safe and environmentally sound hazardous plastic waste handling requires personal protective equipment (PPE) according to the Occupational Safety and Health Administration (OSHA), personal protective equipment is divided into four categories (A, B, C, and D) based on the degree of associated hazard[20]. At least level C of PPE is required for handling the hazardous plastic waste (Levels A, B, and C offer more protection). Table 4 shows an example of level C PPE as described by occupational safety and health administration (OSHA) and environmental protection agency (EPA).

(20) Retrieved from: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.120AppB

Respiratory Protection	Escape Mask or Masks for chemical exposure prevention this mask is for biological infection control	
Clothing	Water-repellent coveralls	
	Safety glasses, or goggles	 
	Hard hat	 According to OSHA Requirements
Gloves	Cut resistant gloves	
Boots/Footwear	Regular boots will be more appropriate	

Table 4: Personal Protection Equipment Level C

12. PLASTIC PRODUCTS LIFE CYCLE

While it is preferable to prevent the generation of plastic waste, once it is generated, it needs to be managed in an environmentally sound manner (ESM) in order to protect human health and the environment. Article 2 of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal defines environmentally sound management (ESM) as: **"Taking all practicable steps to ensure that hazardous waste 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"**.

ESM includes the entire waste management hierarchy, including reduced waste generation, collection, segregation, transportation, storage, and environmentally sound final disposal. The following Figure shows the details of the Plastic products life cycle.

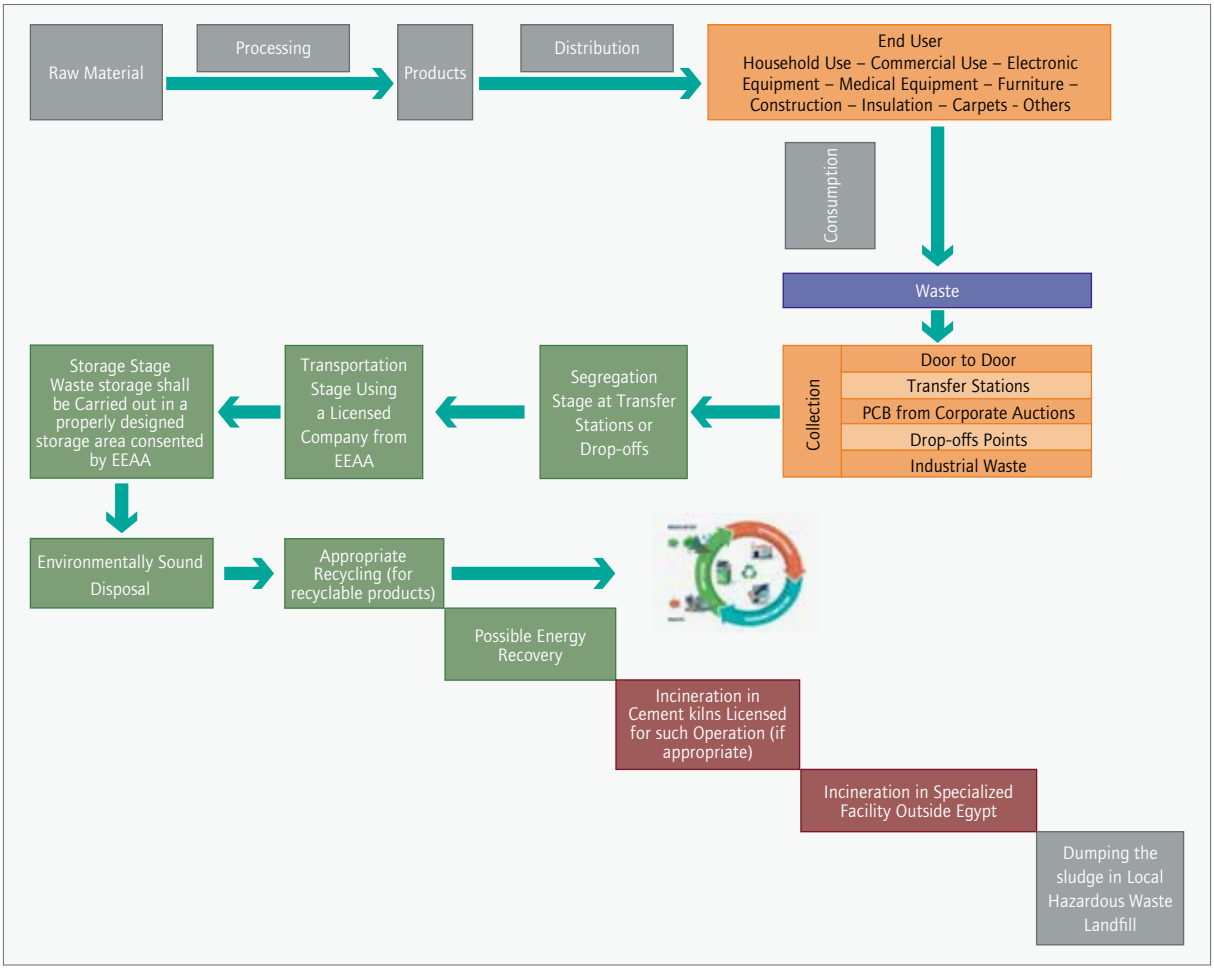


Figure 2: Plastic Products Life Cycle

13. GUIDELINES AND RECOMMENDATIONS FOR HAZARDOUS PLASTIC WASTE MANAGEMENT

The following sections show the proper procedures required for hazardous plastic waste handling, starting from collection and sorting, passing by transporting and storage and ending by the final disposal of such waste. The procedure presents the measures related to the protection of the environment and human health and safety through the prevention and mitigation of the adverse impacts of treatment of waste. It defines both technical and management requirements for operators, and all candidates that can be integrated within the entire process. In addition, protection to the workplace and ambient environment are considered.

13.1 Hazardous Plastic Waste Source and Flow

The following matrix shows the attributed source of each plastic waste type.

#	SOURCE	PET #1	HDPE #2	PVC #3	LDPE #4	PP #5	PS #6	PC #7	Plastic containing BFR
1	Packaging Industry		Y		Y	Y	Y		
2	Consumer Goods Industry	Y		Y		Y	Y	Y	Y
3	Automotive Industry	Y		Y		Y		Y	Y
4	Construction Industry	Y	Y	Y		Y	Y	Y	Y
5	Healthcare Industry	Y		Y		Y	Y	Y	
6	Agriculture Industry	Y	Y	Y		Y		Y	
7	Electrical and Electronics Industry	Y		Y		Y	Y	Y	Y
8	Textile and upholstery Industry	Y		Y		Y			Y
9	Furniture Industry	Y	Y	Y		Y	Y	Y	Y
10	Sports and Recreation Industry	Y		Y		Y	Y	Y	
11	Cosmetics and Personal Care Industry	Y		Y		Y	Y	Y	
12	Food and Beverage Industry	Y	Y	Y		Y	Y		

The following Figure shows the flow of waste over different stages of management:

- Collection
- Segregation
- Transportation
- Storage
- Safe Disposal

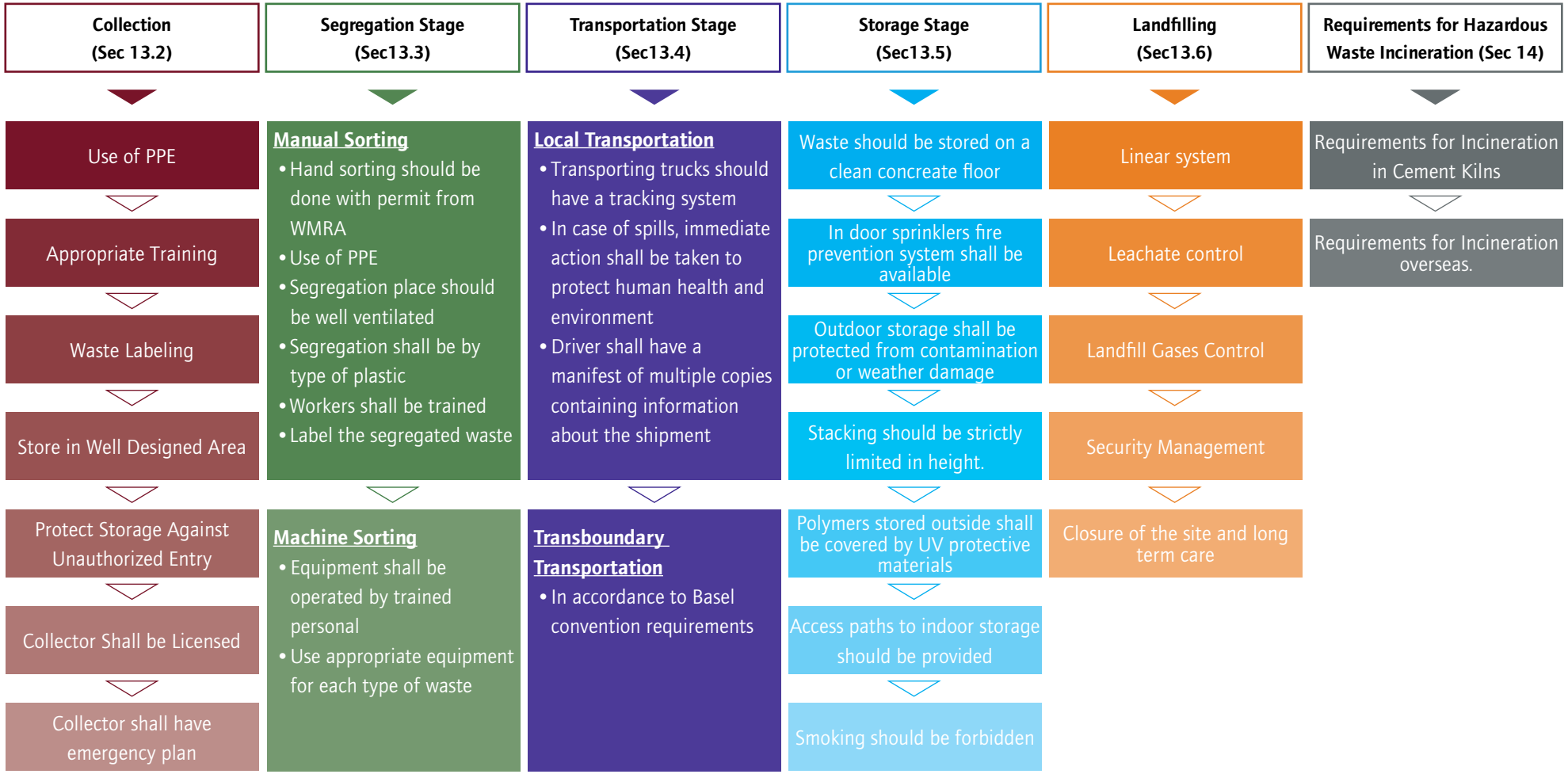


Figure 3: Plastic Waste Management Flow Diagram

The next sections describe the guidelines for all stages of plastic hazardous waste management.

13.2 Guidelines for Collection Procedure

General Requirements for Hazardous Plastic Waste Collection:

- Only companies that have environmental permits from WMRA are allowed to collect such type of waste.
- Collection company shall have a proper facility approved in the WMRA permit

	PLASTIC WASTE TYPE	Products	Characteristics	To Do	Not to Do (Improper Practice)
Recyclable non-hazardous plastic waste	HDPE (#2) 	Milk Jug Non-carbonated drink bottles Motor oil Containers Shampoo & conditioner bottles Soap & Detergents bottles Snack food boxes Cereal box liners, Toys Buckets & rigid pipes, Crates Plant pots & garden furniture Truck bed liners Garden bins & park benches Squeeze bottles Carrier bags High frequency insulation Chemical tank linings Heavy duty sacks General packaging Gas and water pipes.	Semi-rigid, translucent, very tough, weatherproof, good chemical resistance, low water absorption, easily processed by most methods, low cost.	• The collector shall follow minimum requirements with regards to health and safety by the use of appropriate PPE (All workers shall wear level D (at least) PPE). • All staff shall receive appropriate training. • The collection process must be undertaken in a way that minimizes the release of hazardous substances into the environment. • The waste elements should be labelled. • The collected waste should be temporarily stored in a well-designed safe collection area with an impermeable concrete floor and ready for segregation activities. • The collection and storage location should be adequately protected against unauthorized entry. • Collectors should be licensed for hazardous waste. • Collector should have a contingency plan.	• Dumping in municipal landfills. • Storage for a long period to prevent leaching. • Open burning is absolutely forbidden. • Sales to the informal sector.
	LDPE(#4) & PP (#5) 	Plastic wrap & sandwich bags Squeezable bottles Plastic grocery bags Garbage bags Food storage containers & lids Bubble wraps Irrigation pipes Thick shopping bags Wire & cable covers Coating for paper milk pack	**LDPE (low density polyethylene)** is a soft, flexible, lightweight plastic material; it has low temperature flexibility, toughness, and corrosion resistance. It is not suited for applications where stiffness, high temperature resistance and structural strength are required. **PP (Polypropylene)** is Semi-rigid, translucent, good chemical resistance, Tough, good fatigue resistance, Integral hinge property, and good heat resistance.		

	PLASTIC WASTE TYPE	Products	Characteristics	To Do	Not to Do (Improper Practice)
Recyclable hazardous plastic waste	PET(#1) 	Water Bottles & alike Medicine Jars & others Ropes Comb Clothing & carpet fiber Food trays & roasting bags Shampoo Bottles Mouth wash bottles	**Polyethylene terephthalate** is highly flexible, colorless and semi-crystalline resin in its natural state.		
Non-recyclable hazardous plastic waste	PVC Products (#3) 	Pluming pipes Credit cards Carpet backing Floor covering Window and door frame Rain gutters Pipes and fittings Wire and cable sheathing Synthetic leather Clear plastic food wrapping Cooking bottles Teething rings Children's and pets' toys Garden hoses	**Polyvinyl chloride** is hard, rigid, and insoluble in all solvents but swells in the monomer and some chlorinated hydrocarbon solvents.		

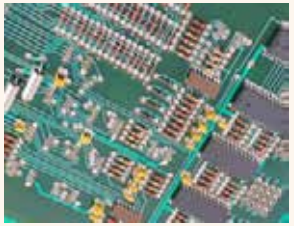
	PLASTIC WASTE TYPE	Products	Characteristics	To Do	Not to Do (Improper Practice)
	PS (#6) Products 	Disposable foam cups Take-away food containers Plastic cutlery Egg cartons Fast food trays Video cases Seed trays Coat hangers Low-cost brittle toys Foam packing and rigid foam insulation Underlay sheets for laminated floor	**Polystyrene** is clear, rigid, brittle and moderately strong. Its electrical properties as a dielectric material are good, though it has relatively low heat resistance. Polystyrene is soluble in most chlorinated and aromatic solvents, though not in alcohols.		
	PC (#7) Products 	Baby bottles Sippy cups Water gallons Medical storage containers Eye glasses Exterior lighting fixtures Metal food cans lining CDs & DVDs Dental sealant	**Polycarbonate** is strong, stiff, hard, tough, transparent Plastic containing FR is rigid, of different colours, could be opaque,		
	Non-recyclable plastic containing FR: 	Printed Circuit Boards, wire cables, Car's accessories, Synthetic textile fabric Furniture containing foam Children toys, Packing material, Insulation foam, Plastic protective clothing, Some building materials, Some medical equipment.	**Plastic containing FR** is rigid, of different colours, could be opaque,		

Table 6: Guidelines for collection procedure of hazardous plastic waste.

13.3 Guidelines for Segregation Procedure

Manual Sorting

- **Manual sorting technique of plastic waste involves identification by shape, color, appearance, trademark of the plastic that distinguishes it for visual identification by the operators.**
- **Manual sorting techniques are useful in such a situation where plastic components are large enough to justify the time and effort involved, since it is very labor intensive, has a bad working environment.**
- **This technique is based on the material identification codes but the possibility of human error cannot be neglected. It has a great advantage in price since it is a relatively cheap method.**

	PLASTIC WASTE TYPE	Description of Products condition	To Do	Not to Do	Not to Do (Improper Practice)
	PET (#1)	• Postconsumer bottle or jar with a screw-neck top and that is clear, transparent green, or transparent light blue. • All blow-moulded bottles and jars less than 2 gallons in size that have a neck or mouth that is smaller than the base including closures (caps, lids, and rings) (e.g., a 2.5 gallon water jug is too large and should be categorized as a plastic bulky item) • Closures (caps, lids, rings and labels) may be left on bottles. • All bottles should be free of contents or free flowing liquids.	• Hand sorting should be done by facilities that possess permits from WMRA. • It should be subject to WMRA inspection. • All workers should wear the proper PPE. • Sorting place should be well ventilated. • Segregation should be classified by type and size of plastic and waste should be contained in large packages. • Workers should be trained to visually differentiate between different types of plastics hazardous and non-hazardous plastic.	• Do not mix with undesirable elements such as metals, and other solids. • Do not mix types of plastics (hazardous with non-hazardous and recyclable with non-recyclable). • Ensure that waste which can be processed for recovery of material and energy (through incineration or any other suitable technology) does not become co-mixed with undesirable elements.	• APR (Association of Plastic Recyclers) guidelines can identify each type of plastic, for the help in manual sorting[21]. • Waste Packing should be in UN approved flexible intermediate bulk containers (FIBCs) UN 13H2/Y

(21) The Association of Plastic Recyclers | Model Bale Specifications (plasticsrecycling.org).

	PLASTIC WASTE TYPE	Description of Products condition	To Do	Not to Do	Not to Do (Improper Practice)
	HDPE (#2)	• Rigid plastic, typically found to be wide mouthed containers and/or oversized items. such as: Carts, crates, buckets, baskets, or other large all-injection HDPE items should be separated first. • Sizes greater than 2 gallons but may be less than 5 gallons should be separated on their own. • Blow-molded containers of any size should be separated on their own.	• Hand picking should be done by visually identifiable waste off a belt conveyor of speed matching with waste quality. • Workers should be trained on sorting and classification of plastic waste. • Each product should be labelled. • Packages should be labelled.		May be a conflict between medium sized rigid containers to be whether HDPE or PP)
	PP (#5)	In the form of Rigid Plastics are sorted as follows: • Bulky PP is items greater than 5 gallons, (e.g., buckets, crates, waste baskets, toys, and storage bins, • Or in small sizes: yogurt cups, microwavable trays, cold drink cups, dishwasher safe storage containers. • Moulded not Blow-moulded containers			

	PLASTIC WASTE TYPE	Description of Products condition	To Do	Not to Do	Not to Do (Improper Practice)
	PS (#6)	PS has 2 forms: foam polystyrene and solid/rigid polystyrene. <u>A) Foam polystyrene (Soft Polystyrene)</u> • Bulk foam Polystyrene blocks from packaging of devices, • As boards and sheets (Styrofoam) in insulations of walls or roofs. (May have a light blue colour). • White polystyrene foam, and mixed colour polystyrene foam used as disposable containers for food and beverages. • Formed by injection moulding. • For efficient recycling it must be with minimal tape, labels, and food stains (must be washed then dried, the moisture content must be less than 5%). <u>B) Solid/rigid polystyrene</u> • Hard and clear in shape, e.g., disposable eating utensils (spoons, forks, hard non-foam plates) • Small hard boxes or containers for packaging electronic appliances. • Soft but non-foam small plastic bags for packaging electronic appliances parts, e.g., mobile charger/screen/battery/ earphones packaging.			

	PLASTIC WASTE TYPE	Description of Products condition	To Do	Not to Do	Not to Do (Improper Practice)
	LDPE (#4)	• Clear/coloured film polyethylene (at least 95% clear). Includes stretch wrap, shrink wrap, and clear, natural bags. • Lightly printed Film packaging (less than 5% of surface covered in ink). • Not including coloured and heavily printed polyethylene films. • Total contamination should not exceed 5% by weight for effective recycling.			
	PVC (#3)	Polyvinyl Chloride is widely available in two broad categories: Rigid and Flexible[22],[23]. • Rigid: It is a tough, lightweight material that is resistant to acids and bases. Mainly used for manufacturing: o In construction industry: such as for vinyl siding, drainpipes, and roofing sheets vinyl fencing, railing and decking, PVC window frames, resilient flooring, vinyl paneling o Other: Phonograph records, traffic cones • Flexible: It is converted to flexible forms with the addition of plasticizers, and making it useful for items such as: o Hoses o Tubing o electrical insulation, o carpet backing o In packaging: meat/deli wrap, shrink wrap, flexible packaging o In medical applications: medical tubing, blood bags			

(22) https://omnexus.specialchem.com/selection-guide/polyvinyl-chloride-pvc-plastic
(23) https://sciencing.com/uses-pvc-plastic-6292581.html

Machine Sorting

This type of sorting includes the use of equipment and techniques that can identify different polymers.

	EQUIPMENT NAME	Technique Description	To do	Not to do	Remarks
	N-) IR, X-Rays (Near) IR, X-Rays[24]	This technique involves irradiating the unsorted, unidentified plastic: With near infrared waves (600 to 2500 meters in wavelength). This has a very high speed of identification. When exposed to near-infrared light waves, different polymers reflect an identification spectrum, this method can accurately identify different.	• Equipment should be operated by trained personnel. • Use this for detection and sorting PVC, as the chlorine atoms in PVC give a unique peak in the X-Ray spectrum that is readily detectable.	• Do not use this method for identification of dark-coloured plastics. • Do not use with wet plastic.	
	Hyper spectral cameras	Are used to separate the plastics. The general idea is to generate a spectral fingerprint of plastic passing on a conveyor to identify it by chemical composition and sort it into plastic type.	• The camera should be used for all types of plastics separation and sorting. • Trained personnel should use the camera.		
	Laser Induced Breakdown Spectrum (LIBS)[25],[26]	It is a technique used to determine hydrogen and carbon constituents present in polymer with the help of spectral analysis. This process is basically used for identifying LDPE, HDPE, PS and PVC by using Nd:YAG laser beam for identification of plastic material. In this process, Nd:YAG laser strike on identified plastic material to determine hydrogen and carbon constituents.		Do not use with contaminated wet plastic waste.	One of the biggest advantages of this process is reliability and easy identification of different polymers depending upon purity level

(24) B.Ruj, V.Pandey, P.Jash, V.K.Strivastava, Sorting of plastic waste for effective recycling (2015).

(25) Russo, R.: Laser Induced Breakdown Spectroscopy, pp. 477–489. Cambridge University Press (2006)

(26) Gondal, M.A., Siddiqui, M.N.: Identification of different kinds of plastics using laser-induced breakdown spectroscopy for waste management. J. Environ. Sci. Health Part A Toxic/Hazard. Substan. Environ. Eng. 42, 1989–1997 (2007)

	EQUIPMENT NAME	Technique Description	To do	Not to do	Remarks
	X-ray Fluorescence	This technique is also known as quantitative analysis. It is used to determine flame retardant materials present in plastic polymers. The material to be inspected is placed in an X-ray tube and will produce X-ray radiation equivalent to optical colour light. Different colours show different energy levels. Time to measure particles depends upon the number of elements to be determined and varies from a few seconds to 30 min. This process is applicable to most of the polymers.	Use with but size of particle should lie between 2 and 4 mm.	Do not use to detect large sizes.	
	Froth Flotation Process	It is another separation technique of plastic polymer. Many authors recommended froth flotation as one of the cheapest methods of polymer segregation[27],[28],[29] But few researchers found that it is not suitable for large-scale segregation and is preferred for mineral processing and for mixed plastic segregation only. Material is inserted into the tank where it is mixed with hot water with the help of electromagnetic feeder. After that, it is mixed with an alkaline solution for alkaline treatment to make pulp. After pulp formation, it feeds into a vibrating tank for rinsing with cold water. Wetted material rinsed with cold water fed into another tank for chemical treatment. The alkaline solution is transferred into a conditioning bank where floated and non-floated parts are separated.	The main requirement of this setup is it requires a proper heating system, huge space for installation and requires frequent cleaning.	• Do not discharge the cleaning before treatment. • The treated water could be re-used.	

(27) Marques, G.A., Tenorio J.A.S.: Use of froth flotation to separate PVC/PET mixtures. Waste Manag. 20, 265–269. (2000)
(28) Takoungsakdakun, T., Pongstabodee, S.: Separation of mixed post-consumer PET-POM-PVC plastic waste using selective flotation. Sep. Purif. Technol. 54, 248–252 (2007)
(29) Shent, H., Pugh, R.J., Forssberg, E.: A review of plastics waste recycling and the flotation of plastics. Resour. Conserv. Recycl. 25, 85–109 (1999)

	EQUIPMENT NAME	Technique Description	To do	Not to do	Remarks
	Magnetic Density Separation	This technique is used to separate LDPE, HDPE and PP. The major advantage of this process is that the complex materials get separated in a single step without changing liquid (modifier in liquid magnetic in nature). In this process, material is wet with boiling water initially to remove heavy plastics known as wetting. To avoid turbulence in the system, air is discharged from the box before placing particles in the stainless steel box. Density and flow speed play an important role as plastic flakes with thickness 1 mm takes a few seconds to reach equilibrium height.			
	Electrostatic sorting technique	Separation can be achieved by employing electrostatic charging of different plastics. This method separates the plastic materials through their differences in electrostatic charges. The materials are sorted by letting them fall freely through an electric field produced between two parallel sets of oppositely charged electrodes and are separately collected according to the triboelectric charge that they have. Electrostatic separation can avoid the problems with contaminants, such as dirt, and can separate polymers of similar density, for e.g., PE and PP. Separation efficiency mainly depends on selective charging and optimum charge density of materials.	One problem is that it is hard to control the gravitational force acting on the falling particles. Therefore, if the particles are too small or very low charged, there has to be a very long separation area between electrodes. However, the efficiency of the above process is poor when processing coarse granular mixtures of insulating materials with particle size>2 mm		

13.4 Transportation of Hazardous Plastic Waste

Hazardous Waste Transport in General and For Hazardous Plastic in Particular[30]

Hazardous waste transporters are individuals or entities that move hazardous waste from one site to another by roads, highway, rail, water, or air. Hazardous waste transporters play an integral role in the hazardous waste management system by delivering hazardous waste from its point of generation to its ultimate destination. This includes transporting hazardous waste from a generator's site to a facility that can store, recycle, treat, or dispose of the waste. It can also include transporting for treatment overseas

Regulations	Who Are the Transporters	To Do	Not to do
Local Transport • Transport shall be through a company that possesses a permit from WMRA, EEAA and Industrial Control Authority. • Types of plastic hazardous waste should be separated in large bags and uploaded and staffed separately in the trucks. • Transport system should follow the rules of the Department of Transportation (Egypt DOT). • Speed limits on roads should be followed.	• Certified companies that own a fleet of trucks equipped to transport hazardous materials and approved from the competent authorities. • The company should employ trained drivers that abide by the rules. • The drivers should wear the proper PPE during the journey especially loading and unloading times.	• The truck should have a tracking system managed by the company's management. • If a transporter discharges or spills hazardous waste, he or she is required to take appropriate, immediate action to protect human health and the environment such as notifying local authorities and identifying the discharge area location. • Transporters must clean up a hazardous waste discharge so that the hazardous waste discharge no longer presents a hazard to human health or the environment. • The driver should have a manifest (record keeping) of multiple copies detailing information about the shipment.	• Do not use improper trucks. • Do not let non trained drivers drive the trucks. • Do not drop the shipment anywhere except at its final destination included in the manifest.

(30) https://www.epa.gov/hw/hazardous-waste-transportation

Regulations	Who Are the Transporters	To Do	Not to do
Transboundary Transport[31] The hazardous waste exporter should abide with the following steps: • Waste should be packed in accordance with the UN approved type of packing. • Notification procedure (see item 14.2 next). • For transport and transboundary movement of hazardous wastes, the following documents should be consulted to determine specific requirements: - Basel Convention: Manual for the Implementation of the Basel Convention (SBC1995a); - International Maritime Organization (IMO): International Maritime Dangerous Goods - Code (IMO 2002); - UNECE: United Nations Recommendations on the Transport of Dangerous Goods, - Model Regulations (UNECE 2007) • Importers and exporters of hazardous wastes must comply with applicable domestic laws and regulations, the relevant international agreements, and regulations established by the other countries involved in the imports, exports route, and any related transit of the hazardous wastes. • Any transboundary movement of hazardous wastes shall be covered by insurance, bond or other guarantee as may be required by the State of import or any State of transit which is a Party.	• Transboundary shipment companies should be certified. • The shipment should follow the route identified in the approval document as per the Basel notification. • Ships should be equipped for any accident and miss- movement to deal with hazardous waste. • Shipment should be traced from the point of start until the final destination. • The transporter should follow the international management provisions for both hazardous waste imports and exports to help ensure safe management of shipments.	• The truck should have a tracking system managed by the company's management. • If a transporter discharges or spills hazardous waste, he or she is required to take appropriate, immediate action to protection human health and the environment such as notifying local authorities and identifying the discharge area location. • Transporter must clean up a hazardous waste discharge so that the hazardous waste discharge no longer presents a hazard to human health or the environment. • The driver should have a manifest (record keeping) of multiple copies detailing information about the shipment.	• Do not start shipment movement without: - notification pursuant to the provisions of Basel Convention to all States concerned; - or without the consent pursuant to the provisions of this Convention of a State concerned; - or with consent obtained from States concerned through falsification, misrepresentation or fraud; - or that does not conform in a material way with the documents; - or that results in deliberate disposal (e.g., dumping) of hazardous wastes or other wastes in contravention of this Convention and of general principles of international law.

(31) Basel convention

13.5 Storage of Hazardous Plastic Waste

Requirements	Regulations and Compliance Issues	To Do	Not to Do
Storing hazardous substances in general and hazardous plastic waste in particular presents unique challenges that must be addressed to maintain a safe working environment. In order to overcome these challenges, the following should be implemented: • Ensuring proper labelling and handling procedures. • Store floor should be of impermeable material to allow no seepage to the underground. • Preventing leaks and spills. • Maintaining appropriate storage conditions (ventilation and temperature control). • Managing the risks of extreme temperatures, impact damage and security issues.	• Regulations to ensure a safe working environment. • Comply with health and safety regulations, employers must adhere to the Control of Substances Hazardous to Health (COSHH) regulations when storing hazardous substances. • These regulations, developed and overseen by the Health and Safety Executive (HSE), require employers to assess risks, determine control measures, and follow a hierarchy of control measures to minimize potential harm associated with the use of COSHH substances.	• All plastics for recycling in shredded or baled form should be stored on clean concrete floors. • If plastic waste is stored indoors, a sprinkler fire-prevention system should be available to prevent large fires and ease firefighting if a fire were to occur. • If plastic waste is stored outdoors, then it should be protected from contamination or weather damage by means of tarpaulins or black polyethylene film. • Contamination of plastics from dust and earth can be avoided by the use of pallets. • Stacking should be strictly limited in height (e.g., no more than 3 bales high) to avoid hazard to employees if a bale falls. • Polymers degrade with prolonged exposure to ultraviolet light, resulting in the deterioration of the physical and chemical properties of the plastic. • Polymers stored outside should be covered with a UV-protective material. • Storage space should not be completely occupied by plastic wastes. There should be access to all areas for material handling equipment and also 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 unauthorized entry and fire-fighting equipment should be readily available. • Smoking should be forbidden in plastics waste storage. • Ready access to all parts of the storage area should be maintained by well-organized and supervised stacking patterns in order to ensure efficient working conditions, easy emergency escape routes for workers and ready access for emergency services vehicles. • Suitable extinguishers should be readily available in the storage area, but staff should attempt to extinguish fires only in their very earliest stages. • A list of the quantities and types of wastes on the premises could be a useful tool for the emergency services to estimate the extension of the fire as many plastics have a high calorific value and once ignited burn rapidly.	• Do not mislabel plastic waste. • Do not ignore the control and tracking of low-quality scrap plastic. • Do not take advantage of the lack of transparency and abundance of actors regarding the plastic waste trade, including waste traders, dealers, and transport and recycling companies.

13.6 Landfilling[32]

No site should be used for the landfill disposal of hazardous wastes unless the geological and hydrogeological properties of the site have been carefully investigated and found to offer maximal safety for public health and the environment.

13.6.1 Liner System

- A landfill should have a liner system to insulate and prevent toxic and other hazardous compounds from being released beyond the confines of the landfill into the environment.
- Sometimes double and even triple liner systems are being selected with liquid collection systems above, below and between liners.
- It is important choosing the liner materials compatible with the wastes to be put in the landfill.
- The estimated service life of a liner in a particular exposure condition is also an important factor in selecting a liner material.
- The bottom and sides of the landfill should be lined with a low permeability containment system.

13.6.2 Leachate Control

- A drainage and collection system for leachate must be installed within the landfill that will allow leachate to be pumped to the surface for treatment prior to discharge. Generated Leachates must be dried to liftable position with a drying mechanism for their final disposal by emission-controlled incineration.

13.6.3 Landfill Gases Control

- Landfill emitted gases should be managed to prevent hazards and when viable it should be recovered for use as an energy source.
- Depending on the nature of the gas released, some form of gas treatment will be recommended to eliminate their undesirable health effects.
  - o Incineration should be employed if the gas is rich in methane and/or volatile hydrocarbons.
  - o Other gas treatments involve sudden quenching followed by wet scrubbing if the gas has a significant hydrogen sulphide content and/or carbon absorption in relatively small amounts of volatile hydrocarbons are present in the gas.
- Emitted gas quality should be measured for regular monitoring, also gas migration control systems should include the monitoring of peripheral boreholes for landfill gas concentration.

13.6.4 For Security Management

- Access to the site should be strictly controlled.
- A suitable buffer zone should be provided around the site, no development should occur near the landfill.
- The buffer zone could incorporate beams and/or trees planted to serve as a visual screen and noise barrier. It will also serve as a margin of safety for neighbors in the event of an accidental release of contaminants, explosion, or fires.
- The site should be secured by a fence to keep unauthorized people from entering. The fence

(32) UNEP Technical Guidelines on Specially Engineered Landfill (D5)

should be posted with signs to identify the site and warn trespassers to stay away.
- Telephone numbers of fire brigade, ambulance, contractor to manage any landslide, police station for reporting of any unlawful criminal activity burial to contact in case of emergency should be posted in an obvious place.

13.6.5 Closure of the site and long-term care

- A levelling layer (compensating for the irregularities of the waste surface).
- A sealing system to prevent infiltration.
- Vegetative cover with continuous care (protection of the covering soil from erosion, maximization of the evapotranspiration rate and landscape quality maintenance).

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 practiced waste disposal method in the majority of countries. Due to the low costs of landfilling alternative waste management options are often unattractive from the current economics point of view. The burial of plastics and contaminated synthetic fibers situation should be minimized to its lowest level by levying taxes on their disposal by burial as they should be used as alternative fuel in proper incinerators.

The Basel Convention has produced technical guidelines on the establishment of specially engineered landfills used for wastes which exhibit one or more hazardous characteristics. 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.

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 groundwater in the landfill. Losses of plasticizers from soft PVC are widely documented in literature. Both phthalates and their degradation products can be detected in landfill leachate.

DEHP, the most commonly used plasticizer in soft PVC, has been classified by the International Agency for Research on Cancer as group 3 (not classifiable as to its carcinogenicity for humans). The PVC polymer itself is generally regarded as being resistant under soil-buried and landfill conditions. The stabilizers 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 release.

Although the reported releases of cadmium, lead organotin and phthalates are 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.

The environmental health problems of burying plastics emanate from their contaminants of plastics as synthetic cloth material soiled with petroleum oil and lubricants, containers of toxic pesticides, dyes, inks, toxic chemicals etc. All those plastics should be incinerated in proper incinerators, gasifiers, pyrolysis as alternative treatment technologies.

14. REQUIREMENTS FOR HAZARDOUS WASTE INCINERATION

14.1 Requirements for Incineration in Cement Kilns

It is of utmost importance that co-processing of hazardous waste in cement kilns is performed only according to best available technologies (BAT)[33] while meeting requirements set out for input, process and emission controls. It is worth noting, in this context, the prevention or minimization of the formation and subsequent release of unintentional persistent organic pollutants (POPs) is the (subject of Article 5 of the Stockholm Convention on Persistent Organic Pollutants).
Incineration in cement kilns should also be in line with UN requirements and Industrial Emission Directive or equivalent and Basel Convention technical guidelines on the environmental sound co-processing in cement kilns (UNEP BC TG), which is based on general requirements for co-processing of hazardous and other wastes in cement kilns[34]:

- An approved environmental impact assessment and all required national/local licenses, permits, authorizations and permissions from EEAA.
- Compliance with all relevant national and local regulations.
- Suitable location, proper infrastructure and equipment for waste storage and processing.
- Reliable and adequate power and water supply.
- Application of BAT for air emissions pollution prevention and control, along with continuous emission monitoring to ensure compliance with regulation and permits (verified through regular baseline monitoring).
- Exit gas conditioning/cooling and low temperatures (< 200°C) in the air pollution control devices to prevent Dioxin, Benzopyrenes and Benzofurans formation.
- Clear management and organizational structure with unambiguous responsibilities, reporting lines and feedback mechanism.
- An error reporting system (incident preventive and corrective action) for employees
- Qualified and skilled employees to manage wastes and health, safety and environmental issues through a well-established integrated environmental management scheme.
- Adequate emergency and safety equipment and procedures, and regular training.
- Authorized and licensed collection, transport and handling of hazardous wastes.
- Safe and sound receiving, storage and feeding of hazardous wastes.

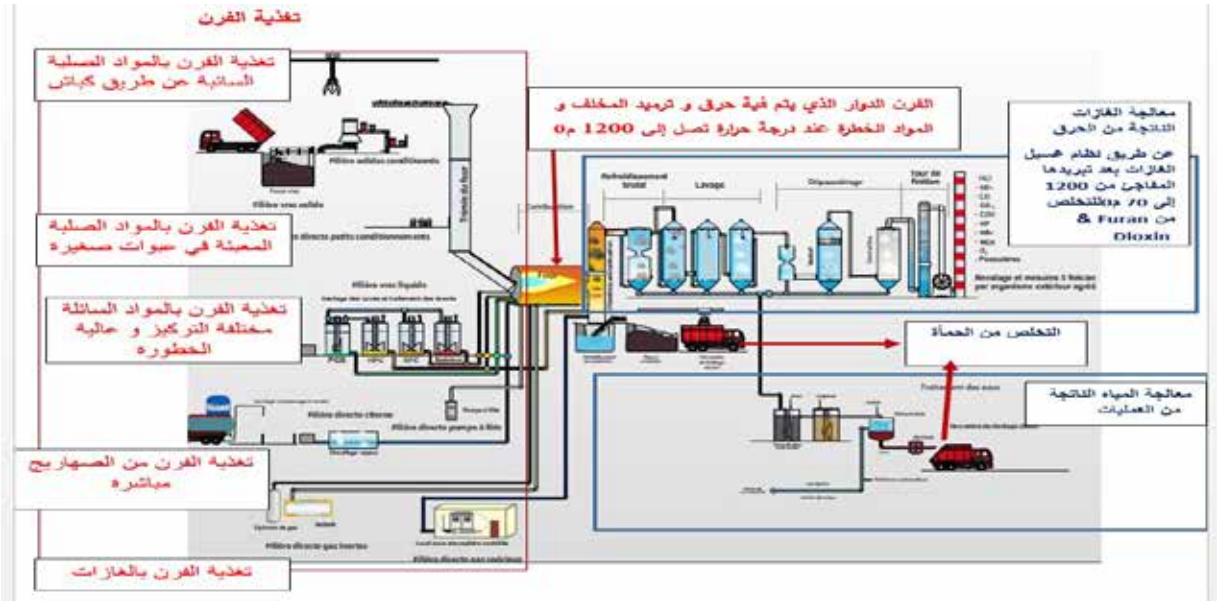
(33) Industrial Emissions Directive 2010/75/EU, (Integrated Pollution Prevention and Control), Best Available Techniques (BAT) Reference, Document for the Production of Cement, Lime and Magnesium Oxide, 2013.
(34) Evaluation Egyptian cement kilns for disposal by co-processing of Obsolete Pesticides (OPs), Part of task I of Contract No. EEAA/SPMP/2, 2017.

- Adequate laboratory facilities and equipment for hazardous waste identification of hazard before acceptance and feeding as a control.
- Adequate record keeping of wastes and emissions.
- Adequate product quality control routines.
- Implementation of an environmental management system (EMS) including a continuous improvement program through continuous training and adoption of proper treatment before final disposal.
- Independent audits (government sanctioned or otherwise), emission monitoring and reporting.
- Stakeholder dialogues with local community and authorities, and mechanisms for responding to comments and complaints.
- Open disclosure of performance and compliance verification reports on a regular basis.

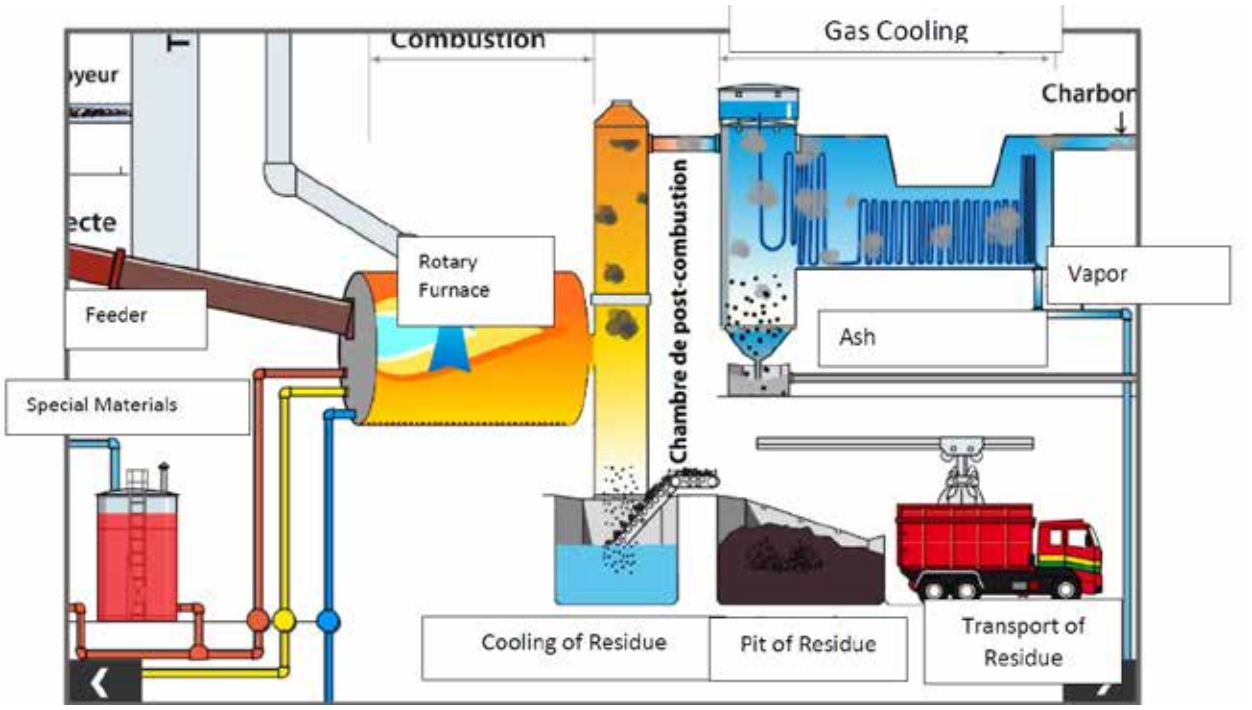
These requirements should be checked by the competent authorities (WMRA & EEAA).

The following shows the state-of-the-art of hazardous waste incineration facility.

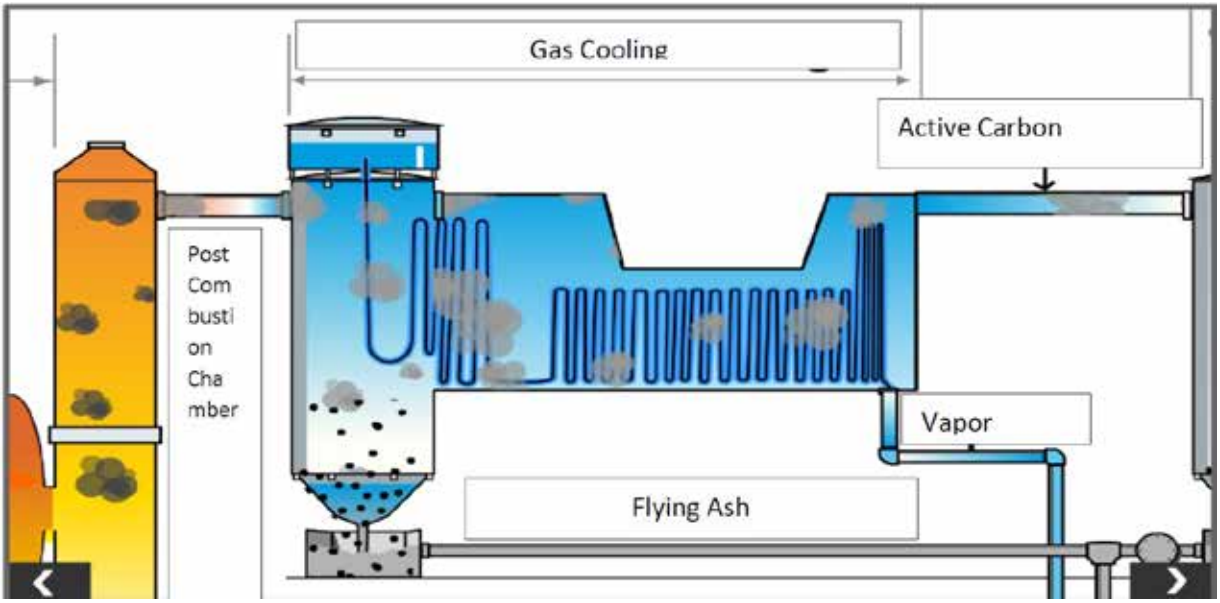
STATE-OF-THE-ART OF HAZARDOUS WASTE INCINERATION FACILITY



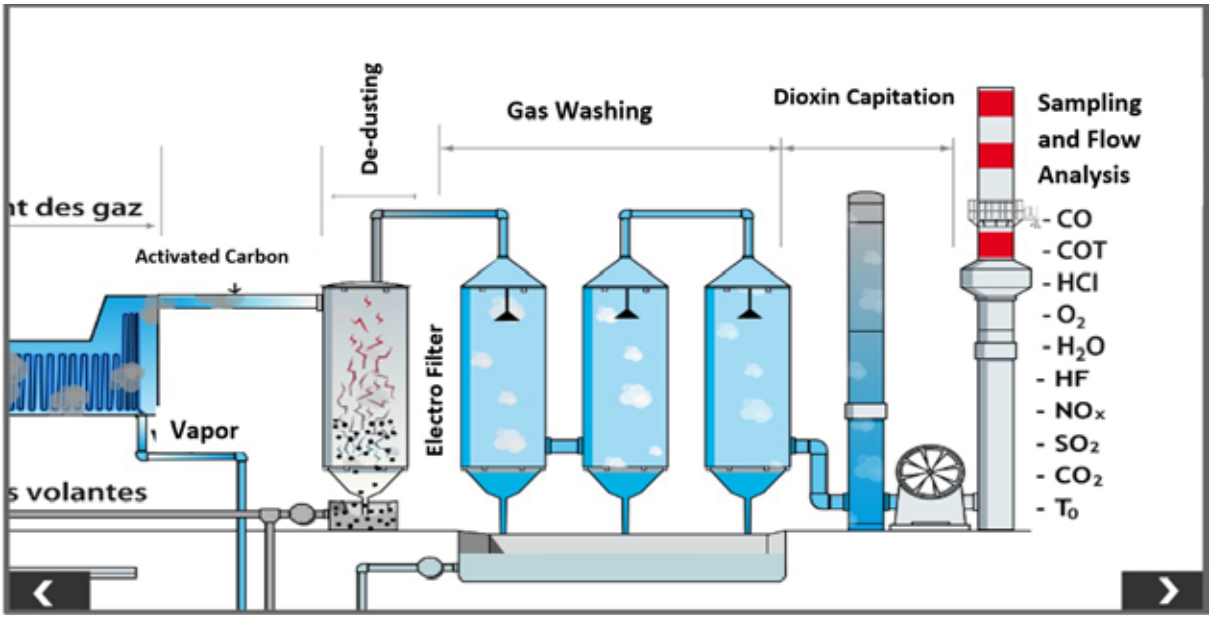
BURNING STAGE



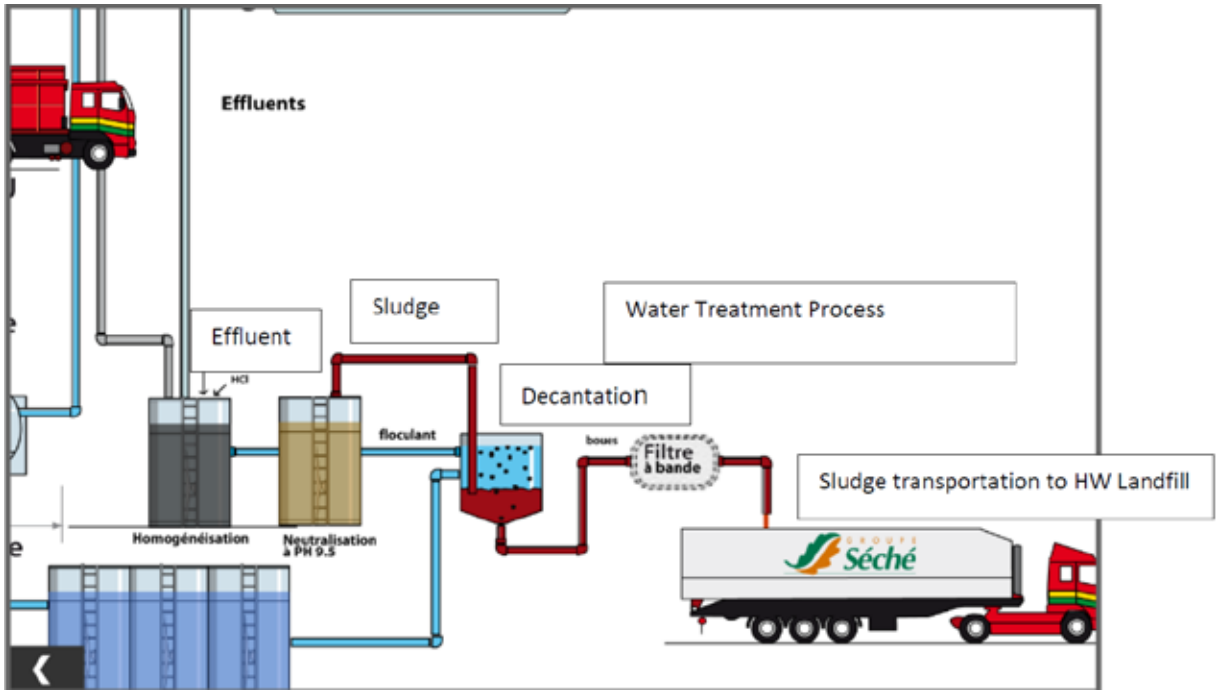
GAS QUENCHING



GAS SCRUBBING



HAZARDOUS WASTE WATER MANAGEMENT



HAZARDOUS SLUDGE MANAGEMENT

14.2 Requirements for Incineration Overseas

The incineration overseas should follow Basel Convention that requires certain procedure as described herein:

14.2.1 Notification

- Only persons authorized or allowed to handle, transport or dispose of wastes undertake such operations.
- Wastes subject to such operation shall be packaged, labelled in conformity with generally accepted and recognized international rules and standards UN Standards)[35].
- Waste should be packed in the packing facility and temporarily stored in an environmentally sound manner.
- Notification: this notification should include the following:
- Declarations and information requested in the Basel Convention and shall be written in a language acceptable by the State of import.
- Prior written consent from the importing and the exporting country and, if appropriate, from transit countries, in addition to a confirmation of the existence of a contract specifying environmentally sound management (ESM) of the waste between the exporter and the owner of the disposal facility are required before any transboundary movements of hazardous and other wastes can take place.
- Parties are to prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes.
- The Convention also requires that information regarding any consignment be accompanied by a movement document from the point where the transboundary movement commences to the point of disposal.

(35) UN approved packaging is a type of box or liner that has been built, tested and certified by the United Nations in order to safely transport dangerous materials – solid or liquid. UN boxes and UN certified packaging is specially produced and tested for its durability, stability and water absorption.

- The Basel Ban Amendment (decision III/1 of the Conference of the Parties to the Convention) would, if it enters into force, prohibit the export of hazardous wastes either for disposal or recycling from Annex VII countries (OECD member countries, the European Union, Liechtenstein), to non-Annex VII countries (i.e., developing countries). Some countries have similar domestic prohibitions.

14.2.2 Transportation

In general, waste should be transported in an environmentally sound manner in order to avoid accidental spills and to track their transportation and ultimate destination appropriately. Prior to transportation, contingency plans should be prepared in order to minimize environmental impacts associated with spills, fires and other emergencies that might occur. During transportation, such wastes should be transported in accordance with the "United Nations Recommendations on the Transport of Dangerous Goods: Model Regulations (Orange Book)". Persons transporting such wastes should be qualified and certified as carriers of hazardous materials and wastes; in particular, transportation on the road to the port of export shall be through a company that has a permit from WMRA to undertake such operation.

For transport and transboundary movement of hazardous wastes, the following documents should be consulted to determine specific requirements:

- Basel Convention: Manual for the Implementation of the Basel Convention (SBC 1995a);
- International Maritime Organization (IMO): International Maritime Dangerous Goods
- Code (IMO 2002);
- UNECE: United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations (UNECE 2007).

15. RECYCLABILITY OF PLASTIC WASTE

Despite the fact that plastic waste recycling is a benefit for the environment, recycling contributes to greenhouse gases reduction and energy conservation. Not all types of plastic are recyclable, and others are to be disposed of through incineration for example. The following Figure shows which of the seven types of plastic are recyclable in general.

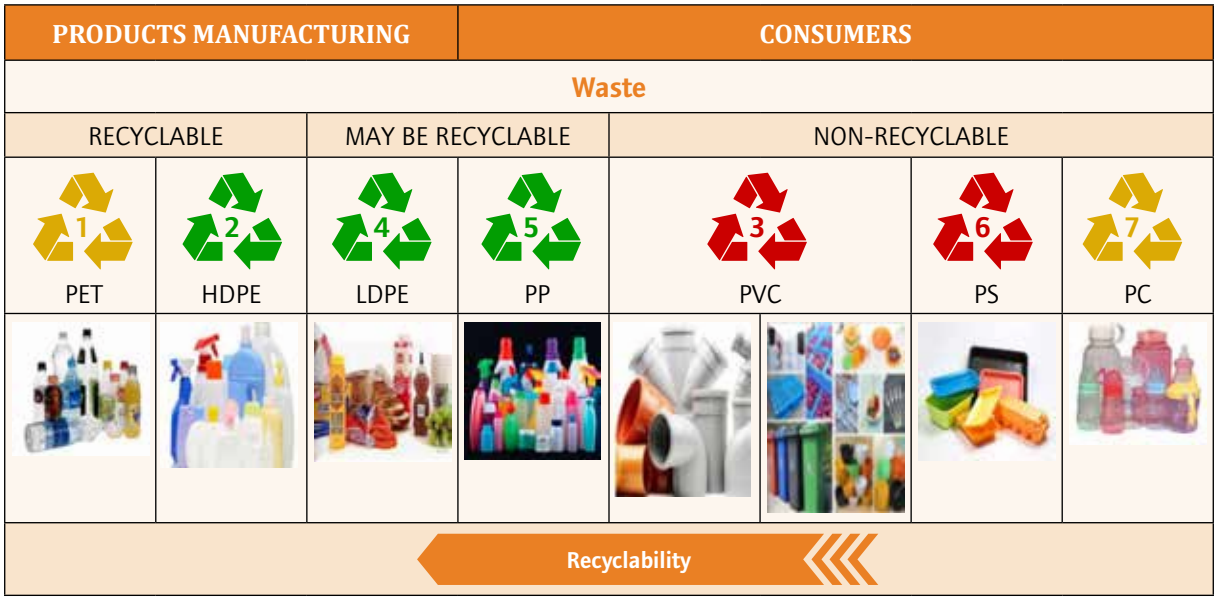


Figure 4 Recyclability of several types of plastic

Since the recyclability of plastic waste is an important issue in this industry, it is helpful to detail the input and output of this process, regarding all types of plastic waste, and its benefits to help decision makers to make the right decisions.

TYPE OF PLASTIC WASTE	Recyclability	Product out of Recycling	Number of Cycle	Remarks & Recommendation
PET (1) – Waste 	Bottle-Bottle		2-3 cycles[36]	When plastic is recycled, even just once, its polymer chain is shortened. If you recycle it another 1-2 times, its polymer chain will become too short and thus lose its quality, making it unrecyclable, so we can conclude that: - We can only recycle plastic 2-3 times before it becomes unrecyclable. - Food and drugs containing bottles should not be made of recycled plastics. - Bottles and containers for other purposes could be manufactured with variable ratios of recycled plastics. - The bottles or containers are produced only in those cases from 100% PET if they meet the standard specifications for their specific use. - Each ton of recycled bottles consumes up to 1.7 ton of used PET[37]. - It is recommended to label the product (RPET1).
	Recyclable to other products	- Fiberfill for soft furnishings and sleeping bags - Pallet strapping - Food packaging not in contact with the food - Thermoformed packaging such as cups and take-out containers		- **The food-grade quality of the recycled PET (food grade R-PET) is ensured by a so-called "challenge test"**[38], which assesses the efficiency of a recycling technology to extract contaminations in the input material to a concentration which does not pose a risk to human health. - The challenge test on recycled PET is evaluated by European Food Safety Authority (EFSA)[39] or U.S.

(36) https://blog.nationalgeographic.org/2018/04/04.
(37) Cradle-to-Gate Life Cycle Assessment of Bottle-to-Bottle Recycling Plant: Case Study, ENVIROINFO 2022: Advances and New Trends in Environmental Informatics pp 3–15.
(38) Critical review on challenge tests to demonstrate decontamination of polyolefins intended for food contact applications, Trends in Food Science & Technology, Volume 49, March 2016, Pages 110-120, ELSIVIER.
(39) https://www.efsa.europa.eu/

TYPE OF PLASTIC WASTE	Recyclability	Product out of Recycling	Number of Cycle	Remarks & Recommendation
				Food and Drug Administration (FDA). - The main applications of non-food recycled PET grades are fibers for non-garment textiles and packaging.
HDPE (2) Waste  	Recyclable	Recycled HDPE could be used in: Shopping bags, storage bins, refuse/ recycling bins, detergent containers, automotive parts, trays, flowerpots, gardening tools, garden furniture, floor tiles, rope and crates, Tupperware, shampoo bottles, bleach bottles, and motor oil bottles[40].	Up to ten times	- The quality of HDPE entering a recycling process is a key factor, the general rule of thumb is that HDPE can be recycled. For some products, this can extend the material life massively, **if properly recycled.**
LDPE(4) Waste 	May be recyclable	LDPE Film can be recycled and turned into many products, such as: Garbage bags/trash can liners, shipping envelopes, carpet treatments, bubble wrap, furniture, floor tiles/ paneling, Plastic lumber, single-use items	Only once[41] (The cycling process starts with heating, which might change the material properties)	It is common to use as single-use plastics, which many of these items end up in our Oceans or Landfills. LDPE is not accepted in all recycling facilities as **the bags can create problems in the sorting machines.**

(40) References and Further Reading:
http://www.wastecare.com/Articles/HPDE_Recycling.htm
http://www.ides.com/pm/HDPE.asp
https://wrap.org.uk/
(41) https://earthwarriorlifestyle.com/blogs/news/plastic-recycling#

TYPE OF PLASTIC WASTE	Recyclability	Product out of Recycling	Number of Cycle	Remarks & Recommendation
PP (5) Waste 	May be recyclable	Because polypropylene material is so adaptable, it can be recycled into many different types of products, including fibers for clothing, industrial materials, kitchenware, dishware, food containers, compost bins, and garden equipment.	PP can be recycled up to 4 times[42]	It can be separated from other plastic types, melted into a liquid, cooled, and turned into pellets, then used to form new plastics. **However, polypropylene loses its strength and flexibility as it goes through the recycling process.**
PVC (3) Waste 	Non-recyclable	NA	This plastic is very seldom recycled.	**PVC is not considered a food safe plastic and should be avoided for food use** due to the high chlorine content in raw PVC, as well as high levels of other hazardous additives added into the manufacturing process to achieve a desired material quality.
PS (6) Waste 	Non-recyclable	NA	Very seldom recycled	It is biodegradable, so it might be incinerated in a dedicated incineration facility.
PC (7) Waste 	Polycarbonate plastics are difficult to recycle mechanically due to the low quality of the recovered material.	NA		It could be recycled using many chemicals using harsh reagents or conditions.

(42) https://earthwarriorlifestyle.com/blogs/news/plastic-recycling#

TYPE OF PLASTIC WASTE	Recyclability	Product out of Recycling	Number of Cycle	Remarks & Recommendation
Waste containing Fire Retardant Materials 	Non-recyclable	NA	No recycling only incineration is allowed	Waste containing fire retardant materials is to be incinerated in a special facility dedicated for such waste safe incineration.

Table 7: Recyclability Details of all Types of plastic

CEDARE
سيدارى

switchmed

Funded by the European Union

UN environment programme