1.7 Guidance: What are plastics and what CoCs are found in plastics

This document is part of the *International Chemicals Management Toolkit for the Toy Supply Chain* developed by the United Nations Environment Programme (UNEP) in collaboration with the Baltic Environmental Forum (BEF) within the framework of the Global Environment Facility (GEF) project ID: 9771 on Global Best Practices on Emerging Chemical Policy Issues of Concern under the Strategic Approach to International Chemicals Management (SAICM).

What are plastics?

"Plastics" is not one single material. Just as "metal" is used to describe more than just iron or aluminium, the name "plastics" is a generic term for many materials that differ in structure, properties and composition. The properties of plastics are so varied that they often replace or supplement conventional materials such as wood or metal.

However, all plastics have one thing in common: They are formed by the tangling or linking of very long molecular chains, the so-called macromolecules (macro = large). These macromolecules are made of many individual building blocks, the monomer molecules (mono = single, meros = part). Plastics are therefore sometimes also called polymers (poly = many).

Plastics are materials whose essential components consist of macromolecular, organic compounds that are created synthetically or by transforming natural products. They are usually malleable by processing under certain conditions (for example under increased heat or pressure). The raw materials for plastic manufacturing are mainly derived from mineral (crude) oil and natural gas but lately also renewable sources of polymers are being used (Hopmann *et al.* 2015).

Plastics can generally be divided into three major material groups (Hopmann *et al.* 2015):

- **Thermoplastics** (thermos = warm; plasso = to form, formable) are fusible and soluble. They can be remolten several times. They are soft to hard-tough or hard-brittle at room temperature. Thermoplastics account for the largest share of plastics in terms of volume.
- **Elastomers** (from the Greek "elastos" = stretchable) occupy an intermediate position: although they are crosslinked, they are not as strong as thermosets.
- **Thermosets** are hard and brittle. They do not deform when exposed to heat. At very high temperatures, they do not melt but carbonise.

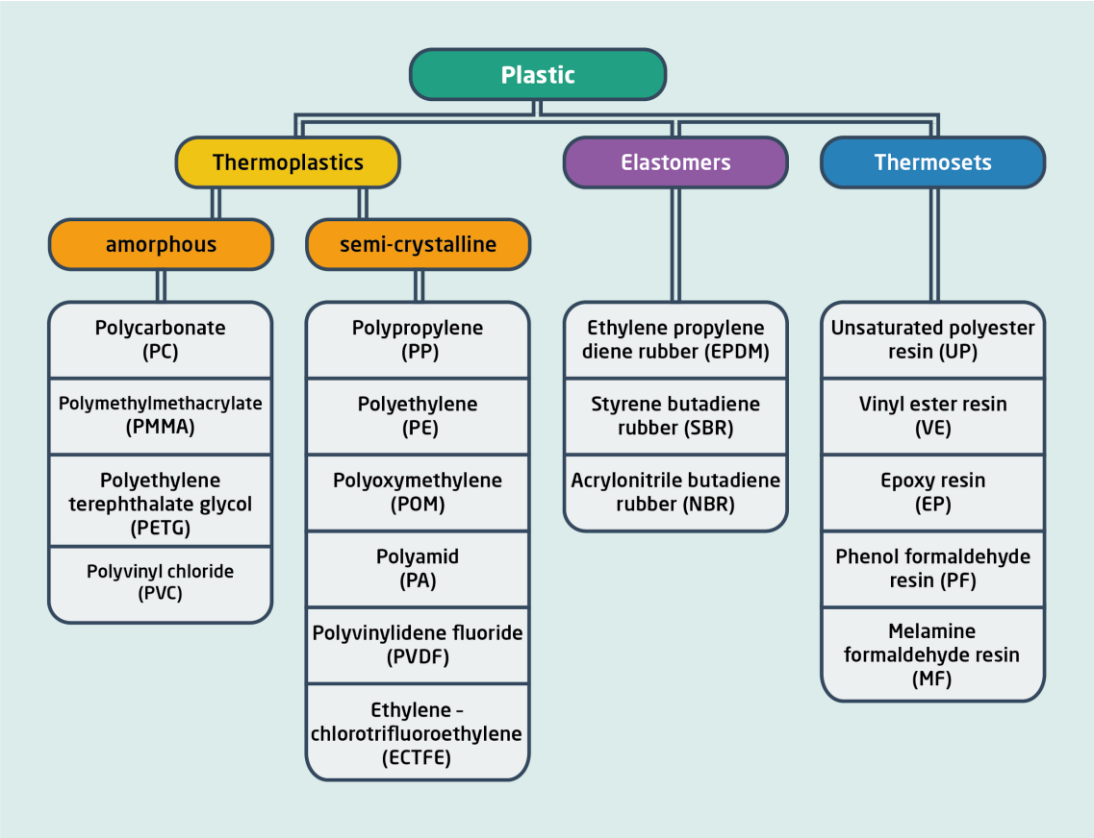

Figure 1: Plastic types (Hopmann et al. 2015)

The most important plastics in order of global demand are polypropylene (PP), low-density polyethylene (LDPE), polyvinyl chlorides (PVC), high-density polyethylene (HDPE) as well as polystyrene (PS), polyethylene terephthalate (PETE) and polyurethane (PUR) (M.R.G. PlasticsEurope 2008).

The properties of plastics can be significantly altered by the addition of additives and by the manufacturing process. The most important additives are fillers, colourants, flame retardants, stabilisers, plasticizers, lubricants and blowing agents (Hansen *et al.* 2013). Fillers are often added to reduce cost and/or increase stiffness, while plasticizers have the opposite effect. Stabilisers are added when the plastics need to be protected from degradation by heat, UV light and oxygen/ozone.

All the aforementioned additives can be mainly divided into the following four categories (Hansen *et al.* 2013):

- **Functional additives** (stabilisers, antistatic agents, flame retardants, plasticizers, lubricants, slip agents, curing agents, foaming agents, biocides, etc.)
- **Colourants** (pigments, soluble azo colourants, etc.)
- **Fillers** (mica, talc, kaolin, clay, calcium carbonate, barium sulphate)
- **Reinforcements** (e.g. glass fibres, carbon fibres)

Most of the hazards from the use of plastics in toys are ensuing from the use of chemicals of concern in additives rather than the polymers themselves (Verbraucherzentrale 2021).

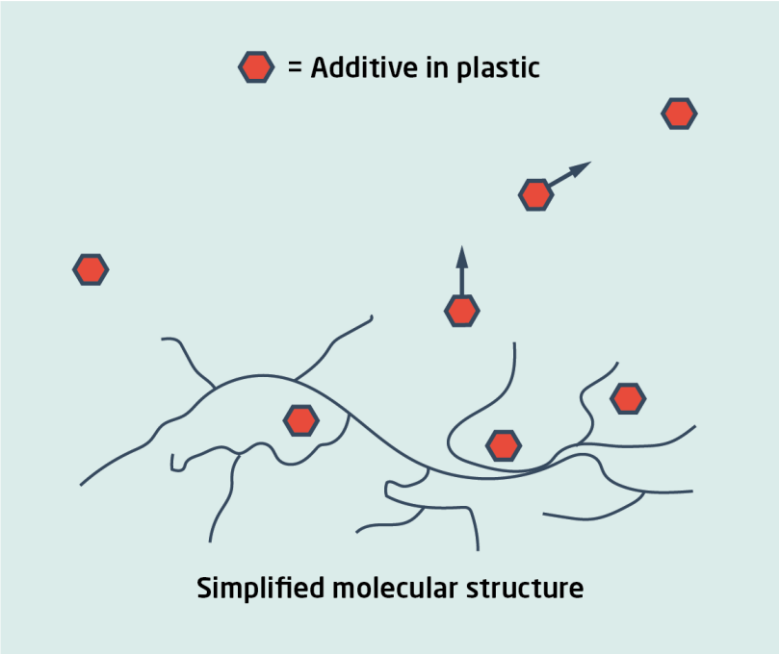

Figure 2: Polymer matrix with additives (red points) (Szymon Grazyk)

Additives (Figure 2: red dots) may be added to the molecular structure (matrix) of plastics. Some are not chemically bound to the polymer matrix and thus can quite easily migrate out of the plastics (indicated by the red arrows) (Wiesinger, Wang and Hellweg 2021). Migration describes the movement of substances within matrices. For example, softeners which are diluted in polymers migrate through the material and eventually reach the surface from which they can evaporate or leach. This process is enhanced by heat, ageing processes of the polymer matrix of the plastics, or contact of the plastics material with fats or acids. When additives migrate out of plastic toys, children can be exposed to them, for example when they touch the toy or put it in their mouth.

To protect children from potential exposures due to migrating additives in plastics, some countries and organisations have set up migration limits for certain chemicals, as explained in the section on legislation.

Plastic additives and types

Additives provide particular functionalities to a plastics material and thereby help to maintain, enhance, and impart certain properties of plastics, e.g. plasticizers enhance flexibility, pigments give colour to a material. If plastics should fulfil a certain function, additives are in most cases necessary and even indispensable. Some plastic types require relatively few or no additives, while others need many of them and in high concentrations. For example, if PVC should be flexible, it must be softened using plasticizers because otherwise it would be rigid and brittle. In this respect, plasticizers must be used in relatively high concentrations to have the desired effect (Polcher *et al*. 2020). For example, a ball made of PVC may contain up to 70 percent of plasticisers (Heinrich Böll Foundation 2019).

Common plastic additives which are found in plastic toys are, for example (Hansen *et al.* 2013):

- Plasticizers (e.g. DiBP, DBP, DEP)
- Flame retardants (e.g. HBCD, DBDE)
- Bisphenol A

In a study, the content of additives in plastics has been researched and compiled. The table below presents some exemplary data on additives. According to the authors of the study plasticizers in soft plastic materials show the highest risk for children (Aurisano *et al.* 2021).

Table 1: Examples of additives in plastic toy and where to find in plastics

Substance	CAS Nr	Function	Plastic (polymer) type*
Triphenyl phosphate (TPHP)	115-86-6	Flame retardant; plasticizer	ABS
Diisobutyl-phthalate (DiBP)	84-69-5	Plasticizer	PUR; PVC
Dibutyl-phthalate (DBP)	84-74-2	Plasticizer	PUR; PVC (soft)
Dioctyl phthalate (DNOP)	117-84-0	Plasticizer	PVC
Di(2-ethylhexyl) adipate (DEHA)	103-23-1	Plasticizer	PUR; PVC (soft)
Di-(2-ethylhexyl)-phthalate (DEHP)	117-81-7	Plasticizer	PUR; PVC (soft); ABS; (E)PS
Tricresyl Phosphate	1330-78-5	Flame retardant	PVC
Bisphenol A (BPA)	80-05-7	Crosslinking agent	PC
Di-(2-ethylhexyl)-terephthalate (DEHTP)	6422-86-2	Plasticizer	n.a.
1,2-Benzenedicarboxylic acid, butyl cyclohexyl ester	84-64-0	Plasticizer	n.a.
Diethyl phthalate (DEP)	84-66-2	Plasticizer	n.a
Diisononyl phthalate (DINP)	28553-12-0	Plasticizer	PUR; PVC (soft)
1,4-Diazabicyclo [2.2.2]octane	280-57-9	Catalyst	PUR
2-Ethylhexyl diphenyl phosphate (EHDPP)	1241-94-7	Plasticizer	n.a.
Diisodecyl phthalate (DiDP)	26761-40-0	Plasticizer	PUR; PVC
Diisoooctyl phthalate (DiOP)	27554-26-3	Plasticizer	PVC; PVA; PUR
Tris(2-chloroethyl) phosphate	115-96-8	Flame retardant	PUR
Hexabromocyclododecane (HBCD)	3194-55-6	Flame retardant	PS
Decabromodiphenyl oxide (DBDE)	1163-19-5	Flame retardant	n.a
Tributyl phosphate (TnBP)	126-73-8	Plasticizer	n.a.
Styrene	100-42-5	Monomer	PS
Ethylbenzene	100-41-4	Solvent	PS

*For detailed information about plastic types see 'Going beyond: Plastic, harmful chemicals and the environment'

For further information on substances (additives), their function and use in plastic types and information on typical concentration ranges can be found in the following publicly available sources:

- ECHA (European Chemicals Agency): *mapping of functional additives or pigments used in plastics registered under EU REACH above 100 tonnes per year*
  https://echa.europa.eu/lt/mapping-exercise-plastic-additives-initiative

- United States Environmental Protection Agency: CPDat (Chemical and Products Database) is a database containing information mapping more than 49 000 chemicals to a set of terms categorising their usage or function in 16 000 consumer products (e.g. shampoo, soap) types based on what chemicals they contain. The database is a part of EPA's Computational Toxicology (CompTox) Dashboard and contains data from other EPA databases including CPCat, CPCPdb and FUse.
  https://comptox.epa.gov/dashboard/

- Substances Search Canada: A search tool to look up substance names and substance identifiers that are referenced in various legislative or regulatory instruments or Government of Canada websites
  https://pollution-waste.canada.ca/substances-search/Substance?lang=en

- The ASEAN – Japan Chemical Safety Database (AJCSD) is developed by ASEAN countries and Japan under AMEICC Working Group on Chemical Industry which consists of representatives from ASEAN countries and JAPAN. The AJCSD is a free database and includes chemical regulatory information, GHS classification results, risk and hazard information, etc. The purpose of AJCSD is to enhance transparency and to reduce compliance risk on chemical safety among those countries.
  https://www.ajcsd.org/chrip_search/html/AjcsdTop.html

- Wiesinger *et al.* (2021) *Deep Dive into Plastic Monomers, Additives, and Processing Aids.* (supplementary information)
  Full publication available at: https://pubs.acs.org/doi/10.1021/acs.est.1c00976

- Aurisano *et al.* (2021) *Enabling a circular economy for chemicals in plastics*. (supplementary data)
  Full publication available at:
  https://www.sciencedirect.com/science/article/pii/S2452223621000699

- Hahladakis *et al.* (2018) *An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling*
  https://www.sciencedirect.com/science/article/pii/S030438941730763X

These additives may not only harm human health but could also have significant impacts to the environment.

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