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

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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.

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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).
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

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

*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*

- 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

- 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*

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

References

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