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Hazardous substances in plastics

Survey of chemical substances in consumer products No. 132, 2014

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Hazardous substances in plastics

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Contents

Foreword

Background and objectives
This report is developed within the Danish EPAs programme on chemicals in consumer products.

The report aims to be a list on hazardous substances in plastics providing information on the function and application of the substances in plastics as well as on the potential for migration and fate by recycling.

The project has covered the following main activities:

- Identification of relevant hazardous substances present in plastics;
- Assessment of the potential for migration for these substances and potential for exposure of consumers;
- Assessment of the fate by recycling for these substances focusing on whether the substances can be expected to be transformed or decomposed in the recycling process and whether it is possible to identify and separate plastic products containing the individual substances.

The process
The survey and assessment has been undertaken by COWI A/S (Denmark) in cooperation with Danish Technological Institute from July 2013 to May 2014. The work has been followed by an advisory group consisting of:

- Shima Dobel, Danish EPA (Chair)
- Dorte Lerche, Danish EPA
- Nils Nilsson, DTI
- Erik Hansen, COWI

Conclusion and summary

This report presents information on hazardous substances in plastics including information on the function and application of the substances in plastics as well as on potential for migration and fate by recycling of plastics.

Selection of substances – a screening process
The substances considered in this project cover substances included on the following lists of hazardous substances:

- The Danish EPA's list of undesired substances (LOUS);
- The SVHC (substances of Very High Concern) Candidate List under REACH;
- The Norwegian list of priority substances;
- ECHA's Registry of Intentions;
- CMR-substances likely to be present in plastic toys (as assessed by the Danish Technological Institute);
- Recognized alternatives to problematic phthalates and brominated flame retardants.

The substances on these lists have been assessed in order to determine whether these substances are used in plastics or for other reasons likely to be present in significant concentration in plastic products. Substances used only as monomers in the production of plastics or in additives incorporated in final plastic products are also included in the assessment process, as these substances in many cases may be present in low concentrations in the final products. The assessment has been carried out as a screening process utilising available sources of information including e.g. EU Annex XV reports, polymer and additive literature and general search on the internet.

By this process a group of 132 chemical substances or substance groups has been identified. The remaining substances on the above-mentioned lists (approx. 330 substances), for which there is no indication of use or presence in significant concentrations in plastics, are listed in annex 1 together with keywords on their uses.

Survey of information for selected substances
For the selected 132 hazardous substances or substance groups information has been collected, assessed and presented to the extent, it has been available. The following issues have been addressed:

- Technical function (of the substance);
- Relevant types of plastics (where the substance is used);
- Main articles groups (for which the plastics with the substance are used);
- Potential for release from plastics (will it migrate?);
- Potential for exposure of consumers;
- Fate by recycling.

The information presented has been collected from scientific literature including study reports prepared for the Environmental Authorities in the Nordic Countries as well as information available on the internet. Important sources of information has been the Annex XV dossiers/reports available from the European Chemical Agency (ECHA) for substances included on the REACH Candidate list

as well as general literature on polymers and additives. This information has been supplemented e.g. by expert judgments by the consultants, who undertook this survey.

The study results

The detailed results of the study are presented in section 3.1-3.11 organised mainly by the function of the substances selected. In this context the following important functions are considered:

- Antimicrobial substances (biocides);
- Blowing agents;
- Flame retardants;
- Colorants (organic);
- Monomers, cross linkers, hardeners, chain modifiers and catalysts;
- UV stabilizers, antioxidants and other stabilizers;
- Plasticisers;
- Solvents;
- Others (substances with different function difficult to place in other categories).

Heavy metals are described in a separate section, as hazardous substances containing heavy metals cover several functions including colorants (inorganic), stabilisers (UV-stabilisers and heat stabilisers) and catalysts.

The focus on monomers, catalyst and other additives in polymer manufacturing processes is based on that residues of monomers and other reactive compounds may be present in the final products. These residues are a result of that not all monomers/compounds succeeds in reacting during the polymerisation process. Typical concentrations of residues left are 0-2 %. Examples of such substances include bisphenol A in polycarbonate, and aromatic amines in polyamide.

Most hazardous substances used as additives are not chemical bound in plastics, but are able to migrate. Migration is the phenomenon that takes place when chemical substances in the plastic move to the surface of the plastic item or to a medium in contact with the item. At the surface the substance may evaporate or be removed e.g. washing or contact with human skin. Both plasticisers, e.g. phthalates, and flame retardants, e.g. brominated flame retardants, are substances well-known to migrate, but many other substances migrate too. The ability to migrate has been assessed for all the substances selected.

The migration rate of chemical substances depends on their size, boiling point, vapour pressure and their solubility in the plastic as well as in the environment or material surrounding the plastic. Migration thus depends heavily on the physical-chemical characteristics of the substance. Small molecules, typically monomers and residual solvents, will migrate fast as they have a low boiling point. Some monomers such as formaldehyde, vinyl chloride and ethylene are all gases and have a high tendency to migrate quickly even at ambient temperatures. Larger organic molecules will migrate more slowly, while inorganic insoluble metal-salts, -complexes and- oxides will not migrate. In all cases migration will decrease with time as the concentration of the migrating substances get lower in the plastic. Substances that do not migrate will only be released by wear and tear including degradation by weathering or by chemical attack.

Only limited precise information is available regarding migration rates. E.g. the migration rate of the plasticiser DEHP is likely to be in the range of 0.1-1% per year or below, while the existing information on release of cadmium by wear and tear (e.g. abrasion) does not allow quantification, but is assessed as very small.

The ability to migrate significantly determines the potential for release of substances from plastics, and thereby the potential for exposure of consumers. For all the substances selected it has been assessed whether exposure of consumers could be expected. Generally for all substances able to

migrate, the possibility exists for exposure of consumers. The knowledge available regarding the applications of the individual substances is, however, not detailed enough to allow that the exposure assessment distinguishes between different consumer groups e.g. adults versus children.

All thermoplastic plastics such as e.g. polyethylene can be recycled by so-called mechanical recycling (remelting). For most additives it is judged that the substances (at least the dominant part) will remain in the materials recycled. The exemptions to this fate will typically be substances as solvents that evaporate easily, monomers etc. exposed to renewed reaction by the recycling process and stabilisers (in particular heat stabilisers) forced to react by the recycling process.

Thermosetting plastics can only be recycled by so-called feedstock recycling where the plastic is degraded into its basic monomers or other chemical substances which can then be used for manufacturing of new plastic polymers. This technology is under development. It is not possible to predict the fate of additives by feed stock recycling, apart from that the additives present in plastic materials treated most likely will be fully decomposed.

Both thermoplastic and thermosetting plastic can be subject to energy recovery by incineration. In this case all organic and most inorganic additives will also be decomposed. Exemptions may be substances as antimony trioxide and molybdenum trioxide.

It has not been tried to assess the opportunities for separation of the specific substances presented here from the waste, as the knowledge available regarding the applications of the substances for most substances is not detailed enough to allow a reliable assessment to be undertaken. The development regarding automatic sorting utilizing NIR as well as X-ray technology indicates that for several substances it will be possible to separate a significant part of the substance out of waste streams assuming that the necessary efforts and costs are invested. Also sorting at the source may in a number of cases be an option depending on the substance in question, its applications and the amount of substance to be separated as well as the costs related to the operation.

Sammenfatning og konklusioner

Denne rapport præsenter information om problematiske stoffer i plast herunder information om funktion og anvendelser af stofferne i plast, potentiale for migration og skæbne ved genanvendelse.

Udvælgelse af stoffer – en screeningsproces
De kemiske stoffer, der er medtaget i dette projekt, omfatter stoffer, som er medtaget på de følgende lister over problematiske stoffer:

- Miljøstyrelsens liste over uønskede stoffer (LOUS)
- Kandidatlisten (SVHC-stoffer, Substances of Very High Concern) under REACH
- Den Norske liste over prioriterede kemiske stoffer
- ECHA's (det Europæiske Kemikalie Agentur) Registry of Intentions
- CMR-stoffer (carcinogene, mutagene, reproduktionstoksiske) sandsynligvis til stede i plastlegetøj (en liste udarbejdet af Teknologisk Institut)
- Kendte alternativer til problematiske ftalater og bromerede flammehæmmere

De kemiske stoffer på disse lister er vurderet for at bestemme, hvilke af disse stoffer der anvendes i plast, eller af anden årsag må forventes at være til stede i væsentlige koncentrationer i plastprodukter. Stoffer der kun anvendes som monomerer ved produktionen af plast eller additiver til plast er også medtaget, da disse stoffer i mange tilfælde kan være til stede i de færdige produkter i lave koncentrationer. Denne vurdering er foretaget som en screeningsproces, der har udnyttet den tilgængelige information herunder EU Annex XV rapporter, litteratur om polymerer og additiver samt internettet.

Ved denne screeningsproces er der identificeret 132 kemiske stoffer eller stofgrupper. De resterende stoffer på de overfor angivne lister (ca. 330 stoffer), som vurderes ikke at blive anvendt i plast eller at være til stede i væsentlige koncentrationer i plast, er samlet i annex 1 sammen med en kortfattet præsentation af deres anvendelser.

Indsamling af information for de udvalgte kemiske stoffer
For de udvalgte 132 problematiske stoffer eller stofgrupper er der indsamlet, vurderet og præsenteret data i det omfang disse data har været tilgængelige. De følgende emner er blevet belyst:

- Stoffernes tekniske funktion;
- De relevante plasttyper (som stofferne anvendes i);
- De vigtigste varegrupper (som plasten med de pågældende stoffer anvendes i);
- Potentiale for frigivelse fra plast (vil stoffet migrere?);
- Potentiale for at forbrugere udsættes for stoffet;
- Stoffets skæbne ved genanvendelse.

Den foreliggende viden er indsamlet fra videnskabelig litteratur herunder rapporter fra miljømyndigheder i de Nordiske lande samt information tilgængelig på internettet. Vigtige kilder til information har været Annex XV dossierer/rapporter tilgængelige fra ECHA for kemiske stoffer inkluderet på REACH kandidatlisten samt general litteratur om polymerer og additiver. Denne viden er sup-

pleret bl.a. af ekspert vurderinger foretaget af de specialister, som har deltaget i arbejdet med denne undersøgelse.

Undersøgelsens resultater
Undersøgelsens detaljerede resultater er præsenteret i afsnit 3.1-3.11, organiseret primært baseret på funktionen af de udvalgte stoffer. I denne sammenhæng er betragtet følgende vigtige funktioner:

- Anti-mikrobielle stoffer (biocider)
- Opskumningsmidler
- Flammehæmmere
- Farvestoffer (organiske)
- Monomerer, hærdere, katalysatorer m.m.
- UV-stabilisatorer, antioxidanter og andre stabilisatorer
- Blødgørere
- Opløsningsmidler
- Andet (stoffer med forskellig funktion, som kun dårligt passer ind i andre kategorier)

Tungmetaller er beskrevet i et særligt afsnit, da problematiske stoffer som indeholder tungmetaller dækker flere funktioner herunder farvestoffer (uorganiske) og stabilisatorer (UV-stabilisatorer og varme stabilisatorer) samt katalysatorer.

At der også fokuseres på monomerer, katalysatorer og andre additiver anvendt ved fremstillingen af plast beror på, at rester af disse stoffer kan være til stede i færdigvarer. Disse rester beror på, at ikke alle stoffer har succes med at reagere fuldstændigt i polymerisationsprocessen. Koncentrationen af rester i færdigvarer vil typisk være på 0-2 %. Eksempler på sådanne stoffer omfatter bisphenol A i polycarbonat, og aromatiske aminer i polyamid.

De fleste problematiske stoffer, der anvendes som additiver i plast, er ikke kemisk bundet i plasten, men er i stand til at migrere. Migration sker, når kemiske stoffer i plast vandrer (migrerer) til overfladen af plasten eller over i et andet medie, som berører plasten. Ved overfladen vil det kemiske stof fordampe eller blive fjernet ved vask eller kontakt med et andet medie (f.eks. menneskers hud, vand eller fedt). Både blødgørere, f.eks. ftalater, og flammehæmmere, f.eks. bromerede flammehæmmere, er stoffer, som vides at migrere, men mange andre stoffer migrerer også. Evnen til at migrere er vurderet og angivet for alle de udvalgte stoffer.

Migrationen af kemiske stoffer afhænger af deres størrelse, kogepunkt, damptryk og deres opløselighed i plast såvel som i det miljø /materialer, som omgiver plasten. Migration afhænger derfor stærkt af det kemiske stofs fysisk-kemiske egenskaber. Små molekyler, typisk monomerer og opløsningsmidler, vil migrere hurtigt pga. det lave kogepunkt. Andre monomerer såsom formaldehyd, vinylchlorid og ætylen er alle gasser, som også migrerer hurtigt selv ved almindelige temperaturer. Store organiske molekyler migrerer langsommere, mens uorganiske uopløselige metalsalte, metalkomplekser og metaloxider ikke migrerer. I alle tilfælde vil migrationen aftage med tiden i takt med, at koncentrationen af det kemiske stof mindskes i plasten. Kemiske stoffer, der ikke migrerer, frigives kun ved slid og forvitring eller ved kemisk nedbrydning.

Der foreligger kun beskeden viden om migrationshastigheder. Migrationshastigheden for blødgøreren DEHP er formodentlig i størrelsen 0,1-1 % årligt eller mindre. Den foreliggende viden om frigivelsen af cadmium fra plast pga. slid og forvitring peger på, at frigivelsen er meget lille. Det er dog ikke muligt at kvantificere denne frigivelse.

Evnen til at migrere bestemmer potentialet for frigivelse af kemiske stoffer fra plast og dermed potentialet for, i hvilket omfang forbrugerne udsættes for disse kemiske stoffer. For alle de udvalgte stoffer er det vurderet, om forbrugerne kan forventes at blive udsat for disse stoffer.

Generelt gælder, at for alle stoffer, der kan migrere, vil der være mulighed for, at forbrugerne kan blive udsat for disse. Den foreliggende viden om anvendelsen af de forskellige kemiske stoffer er dog ikke detaljeret nok til, at det er muligt at vurdere, om der er forskel på, hvordan forskellige forbrugergrupper, f.eks. voksne contra børn, udsættes for de enkelte stoffer.

Alle termoplastiske plasttyper som eksempelvis polyetylen kan genanvendes ved såkaldt mekanisk genanvendelse (omsmeltning). For de fleste additiver er det vurderet, at stofferne (i hvert fald hovedparten) vil blive i de genanvendte materialer. Undtagelserne vil typisk være kemiske stoffer som fordamper let, monomerer som udsættes for fornyet reaktion i genanvendelsesprocessen samt stabilisatorer (især varme stabilisatorer), som tvinges til reaktion gennem genanvendelsesprocessen.

Hærdeplaster kan kun genavendes ved den såkaldte "feed-stock" genanvendelse, hvor plasten behandles ved processer, der kan nedbryde plasten til monomerer eller andre kemiske stoffer, som så kan anvendes til fremstilling af ny plast. Denne teknologi er under udvikling. Det er ikke muligt at forudsige skæbnen for additiver i plast ved feed-stock genanvendelse, udover at additiverne med stor sandsynlighed vil blive nedbrudt.

Både termoplast og hærdeplast kan udsættes for energi genvinding gennem forbrænding. Ved denne behandling vil alle organiske additiver samt de fleste uorganiske aditiver med sikkerhed blive nedbrudt. Undtagelser kan være stoffer som antimontrioxid og molybdæntrioxid.

Det er ikke forsøgt at overveje mulighederne for separation af de kemiske stoffer, der her er udvalgt, da den foreliggende viden om anvendelsen af disse stoffer i de fleste tilfælde ikke er detaljeret nok til at tillade en pålidelig vurdering. Udviklingen mht. automatisk sortering, der udnytter NIR såvel som røntgenteknologi betyder, at det for adskillige stoffer vil det være muligt at udskille en væsentlig del af stoffet fra affaldsstrømme forudsat at den nødvendige indsats og omkostninger er investeret. Sortering ved kilden vil i en række tilfælde også være en mulighed, afhængig af de pågældende stoffer, deres anvendelser og omkostningerne knyttet til opgaven.

1. Introduction

Substances used in plastics in consumer products may migrate from the plastics and thus be a source for exposure of humans and the environment. To some extent these substances will also be present in plastics being recycled. The ongoing efforts to increase recycling of plastics may thus result in that also future generations of plastic products contain and allow for continued exposure to the substances in questions. This project is based on the project, "Prioritized hazardous substances in plastic materials" (see [Hansen et al 2013]) developed by the Norwegian Environment Agency (KLIF) in 2012.

The Norwegian project was dealing with substances included on the Norwegian list of priority substances (see [Norwegian EPA 2013]) as well as substances on the SVHC (Substances of Very High Concern) Candidate list under REACH (as of August 2012) and present in various plastic materials. The Norwegian project compiled information on:

- Characteristics and application of the most used plastic materials;
- The potential for recycling for these plastic materials;
- The substances on the Norwegian Priority List and on the REACH candidate list that will be present in the various plastic materials;
- The function and quantity of these substances in plastics materials;
- The potential for leaching of these substances from plastic materials;
- EU restrictions and Norwegian regulation on the use of these substances in plastics;
- Alternatives;
- Which substances in which products that can be expected to be present in waste.

The Danish project presented here compiles information on the substances listed in the Norwegian project as well as on substances included on:

- The Danish list of undesired substances (LOUS);
- The updated SVHC Candidate list (as of November 2013);
- The EU registry of intentions (as of November 2013);
- CMR(carcinogenic, mutagenic or toxic for reproduction) -substances assessed to could be present in plastic toys
- Recognized alternatives to problematic phthalates and brominated flame retardants.

For those substances assessed to be present in plastic products in significant concentrations compilation of information is focused on:

- The function of these substances in plastics materials;
- The potential for leaching/migration of these substances from plastic materials;
- The fate of the substances by recycling.

The report initially describes (in chapter 2) the process of identifying the substances present in plastics in significant concentrations. The substances identified are presented in chapter 3, while the substances dismissed as not present in significant concentrations are presented in annex 1.

2. Identification of relevant substances

Hazardous substances used in plastics basically covers additives as antimicrobial substances, blowing agents, colorants, flame retardants, plasticisers and stabilisers. To such substances should be added hazardous residues of monomers, catalyst and other additives in polymer manufacturing processes as well as degradation products present in end products (final materials).

The substances considered in this project cover substances included on the following lists:

- **The Danish EPA's list of undesired substances (LOUS) [Danish EPA 2011]**
  The list is a guide for enterprises. It indicates substances of concern whose use should be reduced or halted completely. Substances are included in LOUS if they have a number of undesirable effects and are used in Denmark in significant quantities. The Danish EPA has laid down the following selection criteria for the inclusion of substances in LOUS 2009:
  - Properties of concern according to the EU 'List of hazardous substances', for example CMR categories 1, 2 or 3;
  - Properties of concern identified using computer-based model calculations outlined in the Danish EPA's 'Advisory list for self-classification of dangerous substances' (the Self-classification list);
  - PBT/vPvB substances as identified by the EU;
  - Substances on the EU 'Priority list of substances for further evaluation of their role in endocrine disruption';
  - Substances that are the subject of particular focus in Denmark, e.g. fluorinated greenhouse gasses;
  - Generally only substances used in quantities exceeding 100 tonnes per year in Denmark is included in LOUS 2009. For substances which are the subject of special focus in Denmark, the tonnage threshold can, however, be different.

- **The SVHC (Substances of Very High Concern) Candidate list under REACH [ECHA 2013b]**
  This list cover substances proposed by EU Member States, or ECHA (on request of the Commission) per June 2013, to be identified as a Substance of Very High Concern (SVHC). According to the REACH regulation substances of Very High Concern (SVHC) include substances which are:
  - Carcinogenic, Mutagenic or toxic to Reproduction (CMR), meeting the criteria for classification in category 1 or 2 in accordance with EU regulation (EC) No 1272/2008 on classification, labelling and packaging of chemical substances and mixtures, the so-called CLP Regulation. According to the new CLP Regulation these substances shall be classified as 1a or 1b;
  - Persistent, Bioaccumulative and Toxic (PBT) or very Persistent and very Bioaccumulative (vPvB) according to the criteria in Annex XIII of the REACH Regulation;

- Identified, on a case-by-case basis, from scientific evidence as causing probable serious effects to human health or the environment of an equivalent level of concern as those above (e.g. endocrine disrupters).

- **The Norwegian list of priority substances [Norwegian EPA 2013]**
  This priority list includes substances and groups of substances for which it is Norwegian policy to eliminate or substantially reduce releases. The priority list includes about 30 named substances and groups of substances. These include substances that are persistent and bioaccumulative, that have serious long-term health effects, or that show high ecotoxicity.

- **ECHA's Registry of Intentions [ECHA 2013c]**
  The Registry of intentions contains notifications of intention by EU Member states or ECHA to submit an Annex XV dossier for identification of Substances of Very High Concern (SVHC), for proposing a harmonised Classification and Labelling or for proposing restrictions. The Registry of Intentions should thus be regarded as a list of substances which for different reasons may be considered problematic to human health or the environment and in the future may be restricted, classified or included on the SVHC list.

- **CMR-substances possibly present in plastic toys [DTI 2009]**
  In 2009 The Danish Technological Institute for the Danish EPA prepared a list of substances classified according to the CLP-regulation as CMR-substances (Carcinogenic, Mutagenic or toxic to Reproduction) and possibly present in plastic toys. This list has been used in this context as a best estimate of CMR-substances present in plastic and rubber materials.

- **Recognized alternatives to problematic phthalates and brominated flame retardants.**
  Recent reports on brominated flame retardants and selected problematic phthalates developed on behalf of the Danish EPA [Mikkelsen et al 2013; Lassen et al 2013b] list alternatives to these substances used in plastics. The alternatives listed are assumed to be technical and financial realistic besides being less problematic than the substances they aim to replace. These lists should thus be regarded as lists of substances already replacing problematic phthalates and brominated flame retardants in plastic materials or likely to do so in the future. The alternatives have been included in this study in order to allow comparison to the substances, they aim to replace, although most of the alternatives will not be seen as problematic substances.

The substances on these lists have been assessed in order to determine whether these substances are used in plastics or for other reasons could be to be present in significant concentration in plastic products. In this context attention is also paid to that residues of substances used as monomers or intermediates in the production of plastics or in additives incorporated in final plastic products may in many cases be present in low concentrations in the final products. This assessment has been carried out as a screening process in which the following sources of information have been utilized:

- EU Annex XV and CLH reports
- EU risk assessment reports, and SIDS/SIAR
- Article guide (Swedish Chemicals Inspectorate) "Varuguiden" for plastic and plastic products
- Polymer and additive literature
- Google searches on keywords

- Various internet sources accessed by google searches e.g. Chemicalland and compendium of Pesticide Common Names [Pesticides 2013]
- Chemical suppliers' information on the web inclusive SDS and MSDS available
- Reports from Danish EPA
- Expert assessment by the Danish Technological Institute.

The substances identified as being present in plastics in significant concentrations, are presented in the following chapter 3. A section has been designated to each substance or group of substances assumed to be present in plastics and relevant to consider. A group of substances (e.g. arsenic and arsenic compounds) is included if at least one of the substances belonging to the group is relevant to consider.

As the number of substances relevant to consider is rather high, it has been considered relevant to group the substances based on their function.

The substances assessed not to be used in plastics to any significant extent are together with a brief presentation of their uses listed in annex 1.

As stated above, only substances likely to be present in significant concentration in plastic products are considered. This limitation is introduced as the production of plastic products inclusive of additives may involve many steps in which special substances are used as intermediates in the manufacturing processes.

Chemical reactions may based on reactions kinetics result in residue levels of 0.1 – 2 % in the resultant product. From this follows that going back 2-3 steps in the reaction chain, it is generally not likely that residues of intermediates will be present in the final products in concentrations above trace level. It is therefore assumed, that it generally will not be relevant to consider intermediates more than 1-2 steps back in the reaction chain.

Rubber and elastomers are not considered plastics materials and substances used only in such materials are not included in chapter 3. Regarding textile materials only substances integrated in the plastic matrix is included in chapter 3, while substances used only for treatment of manufactured textile fibres or manufactured/semi-manufactured textiles (e.g. dyes) are not included.

A group of hazardous substances partly presented only in this project is degradation products present in plastics. Aromatic amines in polyamide are examples of such substances. Such substances are only included to the extent they have been included on one of lists of hazardous substances presented above. Aromatic amines are represented by the substance 4,4'- Diaminodiphenylmethane (MDA) (see section 3.6.10). It must be recognised that it is often difficult to identify the source of aromatic amines in plastics. E.g. aromatic amines in polyamide may originate from hydrolyse of aromatic diisocyanate, aromatic amide used as stabiliser or from a black colorant used in polyamide.

It is noted that a number of substances is included on the SVHC Candidate list as well as on ECHA's Registry of Intentions proposed as SVHC candidate. It has not been tried to investigate the reasons for this, and the lists has been utilized in the form they are available on the Internet without further limitations.

3. Hazardous substances in plastics

In this chapter substances which are used or present in plastics in significant concentrations are listed and described. The description is aimed at providing key information on each of the substances regarding their use in plastic.

The key information is in this context limited to the following:

- CAS number;
- Justification (from which lists do the substance originate?);
- The function of the substance;
- Types of plastics where the substance is used;
- Main articles groups for which the plastics with the substance are used;
- Potential for release including leaching or evaporation of the substance from plastic;
- Potential exposure of consumers;
- Fate of the substance by recycling;
- References.

This information, to the extend it is available, is presented in the following sections 3.2- 3.11 describing in total 132 substances. A table has been designated to each substance assumed to be present in plastics and relevant to consider.

The knowledge available on the substances presented differs, however, considerably. For some substances which for many years have been subject to concern and intensive studies, e.g. heavy metals, brominated flame retardants and phthalates, significant information is available and the assessment of exposure by migration and of fate by recycling must generally be regarded as rather solid. For other substances the present information is scarce, as the research and evaluation undertaken for these substances is limited. Consequently the assessments made are more uncertain and less reliable.

It must be stressed that for many of the substances presented, the assessments made regarding tendency to migration and the fate as waste must be regarded as expert judgments made by the consultants responsible for this project. In undertaking these judgments the consultants are drawing on more than 30 years knowledge developed by participation in plastic development projects, consumer protection projects and tests and evaluation carried out for a number of customers in relation to approval e.g. for drinking water and food contact applications.

3.1 Introduction to the information presented

Regarding the information presented for each substance in the following sections 3.2- 3.11 the following considerations applies:

CAS number
The CAS numbers are used as a clear and precise identification of the chemical substance in question. For a group of substances (e.g. arsenic and arsenic compounds) the CAS numbers stated may cover all or many of the substances belonging to the group although only one or few substances from the group is relevant to consider.

Justification
The justification reflects the selection criteria presented in chapter 2, as it is stated from which list of hazardous substances the substance or group of substances originates. All lists containing the substance have been stated. For groups of substances a list has been stated, if just one of the substances belonging to the group is included on the list.

For all substances, apart from the substances included on the list of CMR substances in toy, it has, furthermore, been stated whether the substance is harmonised classified as CMR substance. This is indicated by the letters CMR. For groups of substances CMR has been stated, if just one of the substances belonging to the group is classified as CMR.

For substances present on the ECHAs Registry of Intentions it has been stated, whether the substance or group of substances is included due to harmonised classification and labelling intentions (stated by the letters "CLP"), or due to intentions of being regarded as a SVHC substance (stated by the letters "SVHC"), or due to intentions of being restricted (stated by the word "restriction").

Function (of the substance)
The relevant functions of the chemical substance in plastic are indicated. Typical additives in plastics include antioxidants and other stabilizers, flame retardants, plasticisers, blowing (foaming) agents, antimicrobial substances (biocides), pigments (colorants) and solvents. To this may be added the functions of monomers, intermediate, catalysts, cross linkers, hardeners etc. in production of plastics, all of which may lead to the presence of residues in end products.

The substance tables are generally grouped according to their function with a short introduction to the function of the group and the typical amount added. Substances acting as monomers or intermediates etc. in production of plastics are, however grouped together. Finally, a group named "others" has been established to cover substances, which for various reasons did not fit into other groups.

Relevant types of plastics (where the substance is used)
The most relevant types of plastics are listed for the specific chemical substance. As stated in chapter 2 relevant thermoplastics and thermosetting plastics are included while elastomers (rubber) normally not are listed.

Main articles groups (for which the plastics with the substance are used)
The main articles groups are stated to the extent, they are known.

Potential for release
Migration is the phenomenon that takes place, when chemical substances in the plastic migrate to the surface of the plastic item or to a medium in contact with the item.

It is a rather complicated phenomenon and is for this reason described more detailed below.

Migration can in fact be a required property but in most cases it is not. An example of migration as a required property is the migration of mould release agents to the surface to give a better slip to the mould or to give antistatic properties. Controlled release of drugs from a plastic matrix for precise dosage to the patients is another example of required or controlled migration.

An example of unwanted migration is the migration of plasticisers to the surface of a plastic item from which they may be removed by evaporation, or by being washed away or removed as dust.

Migration of chemical substances in plastic packaging for food or medicine are other examples of unwanted migration as some of the migrating substances may be toxic or give an unpleasant taste to the food or finally destroy the medicine or enhance the degradation of the active substances in the medicine.

The migration rate of organic chemical substances depends on their size and chemical structure. Small molecules, typically monomers and residual solvents, will migrate fast as they have a low boiling point. Some monomers such as formaldehyde, vinyl chloride, ethylene and butadiene are all gases and have a high tendency to migrate quickly even at ambient temperatures and for sure at 100 °C.

The molecular weight of substances used as additives in the plastic are estimated generally to be in the range of 200 – 2000 g/mol. A high molecular weight means a large molecule and a slow migration rate and visa versa. This rule of thumb is used to design additives with low migration rates by designing them with high molecular weight structures. This trick is used for antioxidants, flame retardants and for plasticisers. However, plasticisers and flame retardants based on this principle are used to a minor extend because of the higher cost of the high molecular additives.

Another rule is that the solubility of the additive in the plastic should be high and on the other hand low in a liquid (or food) in contact with the plastic. This can be judged by the parameter log P_{ow} (log K_{ow}) or the solubility data (solubility parameters). Both parameters express the balance between the lipophilic and hydrophilic properties of the substance (tendency to be soluble in fat/oils and water). A low log P_{ow} typically means that the solubility in water is high and a high log P_{ow} means that the solubility in fat/oils is high.

The initial concentration of the chemical substance in the plastic, the thickness of the plastic item, the crystallinity of the plastic and the surface structure of the plastic item all influence the migration rate in a rather complex way but the main route to migration is via the amorphous regions in the plastics.

The flux J of substances (additives and other small molecules like monomers) from materials (plastics) are controlled by
Fick's law $J=-D \times dc/dx$ where

- D is diffusion coefficient of the substance;
- J is the flux (mole of substance per time unit); and
- dc/dx is the concentration difference of the substance over the diffusion distance.

The flux J will decrease over time when the concentration in the product decreases and the diffusion coefficient D will depend on temperature according to an Arrhenius relation

$D=K \, Exp^{(-E/RT)}$

The flux can be integrated over time to a total migration M

For a given time and temperature the total migration can be modelled according to:

$M = C_0 \times t^{0.5} \times K \times EXP^{(-E/RT)}$

Where M: Migration
C_0: Concentration of the migrant in the polymer
t: Time
K: Constant
T: Temperature
E: Activation energy
R: Gas constant

In practise, the migration of substances from plastics is measured in contact experiments under worst case scenarios. Some methods for food contact materials and for pharmaceuticals are standardised while others have to be set up according to the use of the plastic. Special set ups of migration studies are carried out in projects which aim at protecting the consumers against exposure to toxic chemicals from products.

Health assessments are carried out and based on data from these migration studies.

Mathematical modelling is also possible if sufficient migration data are available. For food contact plastics examples of such calculations can be found in Simoneneau [2010].

However it is mandatory to carry out practical migration studies if the modelling results in migration values higher than allowed.

In [KL, 2012] it is stated that only the fraction of additives with molecular weight less than 1000 g/mol is regarded as toxicological relevant as it is very unlikely, that the molecules with more than 1000 g/mol will be absorbed by the gastro- intestinal tract and thus is not considered to present a toxicological risk. Below 600 g/mol most substances are absorbed and absorption rate is determined by other factors than size and shape of the molecule.

Focusing on colorants used in plastics the following considerations has been applied. Four groups of colorants exist:

- Soluble colorants
- Organic pigments
- Inorganic pigments
- Special colorants

The soluble colorants are expensive, have limited light- and heat resistance and have a low tendency to migrate. They are used in PS, PMMA and cellulose plastics to give a bright transparent colour. They are used in amounts of 0.25–5 % w/w. They are pure organic based compounds e.g. azocolorants.

Organic pigments are insoluble and will not easily migrate. They include alizarin derivatives, phthalocyanines, benzidines, carbon black, and metal-azo complexes. They are used as additives in amounts from 0.001-2.5 %.

Inorganic pigments have no migration tendency and have high temperature and UV/VIS resistance. They counts zinc sulphide, iron oxide, cadmium salts, chromium salts, lead and molybdenum salts, ultramarine and titan dioxide.

The term "solid bound" is used in this report and means that although the substance is not chemical reacted with the plastic polymer it is judged that the chemical structure prohibit migration unless the plastic is treated with chemicals which is not intended (e.g. acids/bases or strong oxidation agents).

For some high molecular weight flame retardants it is judged that they will not migrate, but there might be applications where the temperature during service is so high, e.g. in electronics "hot spots" that a certain but low migration can be possible.

Summary of rules of thumb for migration
Having in mind the complexity of migration the following rules of thumb have been elaborated:

- Additives are not chemical bonded in the plastics, except the rather few reactive which is built in the plastic molecule by co-polymerisation (some flame retardants);
- Small organic molecules likes gasses and solvents with low boiling point and high vapour pressure will migrate fast (typical examples are monomers and solvents e.g. reactive solvents used in the polymerization reaction for the plastics);
- Molecules which have a low solubility in the plastic will migrate faster than molecules with a high solubility in the plastic;
- Some organometallic substances will migrate due to fairly low boiling points, e.g. organo tin compounds;
- Chemical substances with a molecular weight higher than 600 g/mol will have low tendency to migrate;
- Inorganic pigments, carbon black, fillers and reinforcing fibres will not migrate unless the plastic material is decomposed by weathering or chemical attack;
- Migration rate will increase with higher temperatures;
- Migration will occur faster in amorphous regions of semi crystalline plastics because of better space between the plastic polymers in the amorphous regions;
- Migration in amorphous plastics will be slowed down as the glass temperature get higher due to less mobility of the plastic polymer chains;
- Migration rate will increase to a contact medium if the solubility of the migrating substances is high in the contact medium (e.g. phthalate plasticisers to vegetable oils), and;
- The migration will decrease with time as the concentration of the migrating substances get lower in the plastic.

Potential for exposure of consumers
The assessment of consumer exposure to toxic substances which might be present in plastic materials is generally based on the assessment of migration of the specific substances. However, also the experience from a number of projects regarding consumer protection against toxic chemicals in a number of different consumer goods carried out by the Danish EPA have been taken into account. In several of the mappings of consumers products chemical substances liberated from plastic based products have been investigated and the possible health risk evaluated for selected substances. Other studies and surveys have also been carried out regarding consumer exposure to toxic chemicals liberated from plastic materials by other Environmental protection agencies e.g. U.S. EPA. The conclusions from these studies are part of the assessment for consumer exposure in this report.

The assessment is focused on stating whether significant exposure to consumers should be expected and do not try to consider the toxicity of the specific substances in question. Generally the knowledge available regarding the applications of the individual substances is not detailed enough to allow that the assessment distinguishes between different consumer groups e.g. adults versus children.

When convenient in the assessment process, bans or other restrictions on the use of the substances in question are mentioned and taken into account. It is, however, not the aim of presentation to present a complete overview of all bans or use restrictions covering the substances and the information presented in this respect must be regarded as non-systematic.

Regarding the working environment special focus should be given to substances likely to evaporate easily due to high vapour pressure or low melting and boiling points. This behaviour will cause a significant evaporation already in the production stage. The substances in question primarily include solvents, but also e.g. certain isocyanates and styrene are relevant in this context.

Several of the chemical substances surveyed in this report have, however, so far not been detailed investigated and the information about the substance and their use is rather limited. This is in particular the case for new substances which are intended to replace banned plastic additives e.g. banned brominated flame retardants.

In those cases where basic information is missing the conclusions made are of course limited. E.g. it is difficult to predict to what extend the alternatives to the banned additives are used in plastic products.

Fate of the substance by recycling
The fate of the substance by recycling has been divided into the fate by mechanical recycling, fate by feed stock recycling, and fate by energy recovery.

According to "End of Life plastics 2013" [S. Hawyward-Higham, 2013] in Europe 50 million tonnes of plastic is consumed each year. Of this amount 10 million ends at landfill and 9 million are valorised (a quarter of this is recycled and three quarters are incinerated to generate electricity). The thermoplastic plastics amount for 80 % of the waste and the thermoset plastics for 20%. The thermoplastics can be remelted but the thermoset plastics like epoxies, polyurethanes and phenolics cannot be remelted and can only be recycled by feed stock recycling.

Further according to Klean Industries the world annual consumption of plastic materials corresponds to 8-10 % of the world's global supply of oil. Klean Industries estimate that globally 80 % of post-consumer plastic waste is send to landfill, 8% is incinerated and only 7 % is recycled [J.Klinkhamer, 2013]

As stated below the assessment of the fate of substances by recycling is focused on the fate by mechanical recycling as both feed stock recycling and energy recovery generally will result in decomposition of the substances, as some chemical bounds are broken for the organic compounds or organometallic complexes, e.g. pyrolysed in the absence of oxygen or combusted by oxidation during energy recovery. For both feed stock recycling and energy recovery the processes involved are very complex and the fate of the substance elements is hardly known or predictable.

Fate of the substances by mechanical recycling
Mechanical recycling covers the process in which the plastic is simply washed, cut or fragmented into small pieces and used as raw materials for new products (remelting process) relevant for the types of plastic and additives in question. Mechanical recycling is mainly applied for the most common thermoplastic materials used for packaging and consumer goods e.g. PE (HDPE, LDPE), PP, PET and PVC, but also for plastics as PS, ABS, PA and TPU. Thermoplastic PU (TPU) is a special type of PU which in contrast to ordinary PU can be remelted. It covers only a minor part of the total market for PU.

The temperatures applied in recycling processes differ between plastic materials and corresponds to the temperatures used for manufacturing of products based on virgin materials. The temperatures

required for e.g. injection moulding processes differs from 150-170°C for flexible PVC to 220-290 °C for PP and 260-280 °C for PET. Generally the injection moulding manufacturing temperatures for typical thermoplastic materials as PE, PP, PS, ABS, PVC, PA and PET will be in the range of 150-290 °C. Other manufacturing processes as extrusion, thermoforming etc. will take place at similar temperatures.

The fate of the substances by mechanical recycling is assessed by comparing the physical-chemical properties of the substances with the knowledge presented above on processing temperatures.

For most additives it is judged that the substances (at least the dominant part) will remain in the materials recycled. Even substances that migrate will in many cases have low migration rates that allow the dominant part to be present in the plastic products at the end of its in-service life as well as in the materials recycled. The exemptions to this fate will typically be substances as solvents that evaporate easily, monomers etc. exposed to renewed reaction by the recycling process and stabilisers (in particular heat stabilisers) forced to react by the recycling process.

The issues of recycling rates are not addressed in the information presented. An optimal recycling rate of 90-93% may be assumed in all cases with mechanical recycling of thermoplastics where more specific knowledge is not available. This rate represents recycling of good quality materials delivered to the recycling plant. By good quality materials is to be understood relatively clean materials separated well in different plastics with a largely uniform content of additives. Difficulties in collection and separation of plastic are not considered in these rates, as such constraint depends heavily on how waste collection is organised in the society.

Separation of plastic materials and specific additives
Successful mechanical recycling requires effective separation of plastic materials according to the different types of plastic and preferably also the dominant additives. Separation can in principle be carried out as separation at the source or by automatic waste sorting.

Separation at the source are relevant for products being used in closed (or almost closed) loop cycles (e.g. beer boxes, PET bottles etc.) or for products being easy to identify and available in significant quantities making separate handling feasible. Although recycling systems exist for several products these products are normally not related to specific additives. Separation of products as a way to separate out specific additives is in principle realistic, but will generally only allow for separation for a part of the substance in circulation besides that it will be difficult to make a precise limitation of the products to be collected.

The following examples illustrate the complexity of the situations to be considered:

- Cadmium was the dominating UV-stabilizer in PVC-windows and doors up to the end of 1980'ties. After that time it was in Denmark replaced by lead-stabilizers (again replaced by other stabilizers about year 2000), besides that plastics doors made of other materials (PP, HDPE) was marketed during the 1990'ties.
- Flame retardants are likely used in all electronic products. Before implementation of the EU RoHS directive these flame retardants were dominantly brominated of the additive kind. After the implementation additive brominated flame retardants are widely replaced by other flame retardants inclusive of reactive brominated flame retardants.
- Phthalates are dominantly used in flexible PVC. Other flexible plastics include LDPE, polyester etc. Flexible foamed plastic will dominantly be PVC or polyurethane.

Automatic waste sorting of mixed plastics will typically involve the steps of pre-sorting, shredding, sieving and separation according to polymer type by NIR identification or X-ray identification, density, and colour. In the shredding process the plastic are typically reduced to flakes in the size of 10 mm x 10 mm.

Near-infrared spectroscopy (NIR) allows for automatic identification and separation of different plastic types. The technology can achieve about 90 % sorting efficiency by a single passage of the plastics, but cannot, however, separate black plastic and coated plastic. [Jakobsen et al, 2014].

X-ray identification can be used to identify specific elements in the plastic as e.g. chlorine, brome and heavy metals. Specific elements can thus be used as indicators of hazardous substances e.g. brome can be used as indicator of brominated flame retardants.

Density can also be used for separating a number of plastics. Among bulk plastics in particular PVC distinguish itself having a density of 1.38 - 1.53 g/cm3 significantly above the density of PE, PP and PS (0.9 - 1.07 g/cm3). Several technical plastics will, however, have density close to or above the density of PVC.

Colour separation can be used in special situations, e.g.:

- Cadmium and lead has historically been important substances in yellow and red colours. The use of cadmium stopped about 1990 and the use of lead about 2000. Many other yellow and red colours are, however, available on the market. Due to this sorting based on X-ray identification should be preferred.
- Cobalt acetate is used for providing the transparent blue tint often used in PET bottles. This colour is, however, in the process of being out phased. Also in this context sorting based on X-ray identification of cobalt should be preferred.

Colour separation is therefore mainly used to obtain a certain colour quality (e.g. white plastic or green plastic) and is in particular used in separation of PET bottles, as the colour quality influences the sales price for the sorted bottles.

The various separation techniques available on the marked today for plastic recycling are surveyed in a recent project supported by the Danish EPA [Jakobsen et al, 2014].

However, fool proof technologies do not exist, and it is still a challenge to assure that health- and environmental unwanted substances do not contaminate the different plastic types recycled. This unsolved issue is addressed in an ongoing project INNOSORT at the Danish Technological Institute. In this project spectroscopic studies using advanced hyperspectral imaging techniques and sensor fusion mathematics are focussing on how to sort these substances from the plastic waste.

It has not been tried to assess the opportunities for separation of the specific substances presented here, as the information available regarding the applications of the substances for most substances is not detailed enough to allow a reliable assessment to be undertaken. The development regarding automatic sorting utilizing NIR as well as X-ray technology indicates that for several substances it will be possible to separate a significant part of the substance out of waste streams assuming that the necessary efforts and costs are invested. Also sorting at the source may in a number of cases be an option depending on the substance in question, its applications and the amount of substance to be separated as well as the costs related to the operation.

Fate of the substance by feed stock recycling

Thermosetting plastics as epoxies and ordinary PU cannot be recycled mechanically, but feedstock recycling is possible. However, only a few feedstock recycling plants are actually operating in Europe and this technology is still under development. In many countries energy recovery by incineration has been prioritized as compared to recycling and in particular feedstock recycling.

By feed stock recycling (or chemical recycling) the principle is to recover the plastic monomers by depolymerisation at temperatures so high that the chemical bonds between the monomers can be broken by cracking or by hydrolysis of the bonds for certain plastic polymers with bonds that can be

hydrolysed (by water or glycols) e.g. polyamides, polyurethanes and polyesters. The processes used are very complex and it is not possible to predict the fate of the substances by feed stock recycling apart from that the additives present in plastic materials treated most likely will be decomposed.

To be economical feasible the amounts of plastics feed to the plants must be very high and this can explain why feed stock recycling is not used in recycling plants in Denmark besides that in Denmark energy recovery by incineration until recently has been prioritized as compared to recycling and in particular feedstock recycling.

According to [Jensen et al 2000] there are plants for feed stock recycling in Germany, France and USA. These plants convert polyamides, polyurethanes and PET to e.g. monomers. In Germany a plant exist which degrade PVC to petrochemical products.

Klean Industries Inc. [Klinkhamer 2013] claims that in Japan a plant for feed stock recovery from cell phones has a capacity of 20 tonnes per day (installed 2012) and another plant in Japan for recycling of municipal and industrial mixed plastic waste with large loadings of PVC and PET has a capacity of 50 tonnes per day (installed 2000-2011).

Fate of the substances by incineration
For European incineration plants the EU directive 2000/76/EC requires incineration temperatures for municipal and industrial waste of at least 850° C and for hazardous waste of at least 1100°C for at least 2 seconds. To the best of knowledge these conditions of operation ensures adequate decomposition of combustible materials inclusive of complex molecules. It can therefore be assumed that hazardous substances apart from elements generally will be decomposed by controlled incineration. Elements as metals will typically be converted into oxides.

Formation of hazardous substances e.g. dioxins and PCBs and acids as hydrochloric acid and hydrofluoric acid may, however, take place again after the incineration process in the chimney system by "de novo synthesis" and similar processes. These emissions are typically controlled by use of activated carbon in the air filtering system. Concerning other substances than halogenated substances and acids little knowledge is available regarding processes taking place and the substances formed and the issue is therefore not addressed further.

References
For each substance and/or group of substances for which information is presented in section 3.2-3.11 the relevant references has been stated in the bottom row of the table. The references have, furthermore, been organised into the general list of references presented at the end of the report.

However, the REACH Annex XV reports or dossiers, which for all substances on the candidate list have been an important source of information are only listed under the relevant tables and not included in the general list of references. All these reports are available from ECHA on the internet.

3.2 Antimicrobial substances

Antimicrobial substances (biocides) are used in plastic to protect these materials from attack and degradation by microorganisms.

Natural or bioplastic materials can be attacked by microorganisms, whereas synthetic plastics made from synthetic monomers are often highly resistant. However, some microorganisms are capable of using additives like plasticisers as energy source in presence of water. To prevent that, antimicrobial substances can be added to the polymer [Subraminian 2013].

Typical amount of antimicrobial substances in plastic products is 0.001-1 % (w/w) [Hansen et al, 2013]. The dominant fields of application are deemed to be plasticised PVC, followed by polyurethane, polyethylene and polyester.

The ability to migration differs between substances. Triclosan and tin compounds will migrate while the key arsenic compound (10,10'-oxybisphenoxarsine (OBPA)) is solid bound without significant migration. The potential for exposure of consumers is generally assessed as low, but tributyltin compounds will have a high tendency to migrate to fatty substances.

Regarding recycling the fate also differs by substances. Tin compounds as biocides are only used in polyurethane (PUR) that cannot be mechanical recycled, but has to be treated by feedstock recycling or incineration. In Denmark only incineration is used leading to destruction of the tin compounds and collection of tin with clinker and air cleaning residues from incineration.

Regarding triclosan and arsenic compounds mechanical recycling is possible and the substances will not be decomposed or forced to evaporate from plastics by the recycling process. Consequently the substances will dominantly be present in recycled materials.

3.2.1 Arsenic and arsenic compounds

Substance	Arsenic and arsenic compounds
CAS Number	7440-38-2; 7778-39-4; 58-36-6; 1303-28-2;1327-53-3; 7784-40-9; 7784-42-1; 15606-95-8; etc.
Justification	Norwegian priority list; Candidate list; Registry of intentions (CLP, SVHC); CMR.
Function	10,10'-oxybisphenoxarsine (OBPA) is an antimicrobial (accounting for 70 % of the demand for antimicrobials in plastics) [Zweifel et al, 2009]. Other substances included in the substance group may be used for manufacturing of OBPA.
Relevant types of plastics	Plasticised PVC (have a particular susceptibility to microbial attack and is by far the main plastic in which antimicrobials are incorporated), followed by polyurethane, and then LDPE and polyesters [Zweifel, 2001].
Main article groups	Examples include: shower curtains, floor coverings, wall coverings, coated fabrics, marine upholstery, automotive vinyl trim, vinyl moulding, tarpaulins, awnings, gaskets, weather stripping, caulking, ditch liners and swimming pool liners, and textiles [US EPA, 2009b].
Potential for release from plastics	OBPA will likely remain bound without significant migration in the plastics (molecular weight: 502; very low vapour pressure) [US EPA 1993]. Release by wear and tear mainly.
Potential for exposure of consumers	It is judged that arsenic and arsenic compounds used for the production of OBPA will not be present in concentrations which will be of concern for the consumers. As the migration tendency of OBPA is low due to the high molecular weight it is judged that the risk for consumer exposure is very low.

Substance	Arsenic and arsenic compounds
Fate of the substance by recycling	OBPA is judged mainly to remain in the plastic by mechanical recycling processes.
References	US EPA (1993). 10,10'-Oxybisphenoxarsine (OBPA) Reregistration Eligibility Document. National Service Center for Environmental Publications (NSCEP). US EPA (2009b). 10,10'-Oxybisphenoxarsine (OBPA) Summary Document: Registration Review. Document ID: EPA-HQ-OPP-2009-0618-0004. Zweifel, H. (2001). Plastics additives handbook. 5th edition. Carl Hanser Verlag, Munich. Zweifel, H., Maier, R.D., Schiller, M. (2009). Plastics additives handbook. Carl Hanser Verlag, Munich.

3.2.2 Bis(tributyltin)oxide (TBTO)

Substance	Bis(tributyltin)oxide (TBTO) - see also section 3.35.
CAS Number	56-35-9
Justification	Norwegian priority list; Candidate list; Registry of intentions (SVHC).
Function	Antimicrobial agent, intermediate.
Relevant types of plastics	Polyurethane (foam) and other polymers (unspecified), impurities in mono- and dibutyltin stabilisers for plastic. [Annex XV dossier].
Main article groups	Polyurethane foam; polymers used in products such as flooring, tiles and carpeting [Annex XV dossier]. Are today according to [ECHA 2009b] only used as intermediate.
Potential for release from plastics	Molecular weight: 596.12 g/mol, melting point: < - 45 °C, boiling point: 220-230 °C at 13 hPa, vapour pressure: 0.00000085 – 0.00016 hPa at 20 °C, water solubility: 4.0 mg/l (at pH 7.0; 20 °C; distilled water), log K_{ow}: 3.2 – 4.05 [Annex XV dossier]. Assessed as a volatile compound. Not solid bound and will migrate. [Nilsson, 2012]. By migration and by wear and tear. Given sufficient time, a significant part of the substance will probably be released. [Nilsson, 2012].
Potential for exposure of consumers	The substance is banned in EU and will not be present in new products. Exposure to consumers is on this background judged to be only on subtrace level in plastics as it is only present as an impurity in other tin based antimicrobial agents. For PUR only exposure from products marketed before the EU ban was implemented might happen, but the risk for exposure is judged low.
Fate of the substance by recycling	PUR can only be recycled by incineration or feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised. The tin will be distributed between the slag and the gas cleaning products.

Substance	Bis(tributyltin)oxide (TBTO) - see also section 3.35.
References	Annex XV dossier Report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_norway_pbt_tbto_20083006_en.pdf ECHA (2009b). Background document for bis(tributyltin) oxide (TBTO). Document developed in the context of ECHA's first Recommendation for the inclusion of substances in Annex XIV. ECHA 1. June 2009. Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014. RPA (2007). Impact Assessment of Potential Restrictions on the Marketing and Use of Certain Organotin Compounds. European Commission, Directorate-General Enterprise and Industry. Brussel. http://ec.europa.eu/enterprise/sectors/chemicals/files/studies/organotins_en.pdf

3.2.3 Organic tin compounds (tributyltin, triphenyltin)

Substance	Organic tin compounds (tributyltin, trifenyltin) - see also section 3.8.6
CAS Number	76-63-1, 76-87-9, 379-52-2, 639-58-7, 76-87-9, 900-95-8, 56-35-9, 1461-22-9, 2155-70-6, 26354-18-7, 688-73-3
Justification	Norwegian priority list; CMR.
Function	Biocide (trisubstituted tin compounds - tributyltin, trifenyltin). Impurity in e.g. disubstituted tin compounds used as stabiilizers in PVC and catalyst in production of polyurethane foams.
Relevant types of plastics	Polyurethane foam and PVC.
Main article groups	Dibutyltin compounds are used preferably as stabilizers in colourless and/or transparent PVC plastic articles [KEMI 2012]. Examples on transparent PVC products include roof panels/windows, transparent partitions for clean rooms, packaging (blisters), containers, bottles and films (wrapping). Tributyltin: Polyurethane foam used in furniture; fibrefill polymers used in products such as flooring, carpeting; back-coating of textiles used in upholstery and fabrics treated with a coating (e.g. PVC) containing tributyl tin [Annex XV dossier; US EPA, 2008].
Potential for release from plastics	Assessed as a volatile compound. Not solid bound and will migrate. Release will take place by migration and by wear and tear. Given sufficient time, a significant part of the substance will probably be released. [Nilsson, 2012].
Potential for exposure of consumers	The MW is 290.05 g/mol for tributyltin and 385.5 g/mol for triphenyltin. The consumer may be exposed to the substances by inhalation, dermal exposure or orally due to the low molecular weight. The log P_{ow} especially for the triphenyltin is higher than 3, which means that the substance will have a high tendency to migrate to fatty substances.

Substance	Organic tin compounds (tributyltin, trifenyltin) - see also section 3.8.6
Fate of the substance by recycling	PUR can only be recycled by incineration or feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised. The tin will be distributed between the slag and the gas cleaning products. PVC may be mechanical recycled. The organic tin compounds added as biocide to PVC will mainly remain in the PVC by the recycling process. If PVC is energy recycled by incineration the fate of tin will be the same as for PUR.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_norway_pbt_tbto_20083006_en.pdf ECHA (2009b). Background document for bis(tributyltin) oxide (TBTO). Document developed in the context of ECHA's first Recommendation for the inclusion of substances in Annex XIV. ECHA 1. June 2009. KEMI (2012). Dibutyltin compounds. http://apps.kemi.se/flodessok/floden/kemamne_eng/dibutyltennforeningar_eng.htm (Nov.2012). Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014. US EPA (2008a). Reregistration Eligibility Decision for the Tributyltin Compounds: Bis(tributyltin) oxide, Tributyltin benzoate, and Tributyltin maleate (Case 2620). http://www.epa.gov/oppsrrd1/REDs/tbt-compounds-red.pdf

3.2.4 Triclosan

Substance	Triclosan $C_{12}H_7Cl_3O2$
CAS Number	3380-34-5
Justification	Norwegian priority list.
Function	Biocide [NICNAS, 2009].
Relevant types of plastics	Polyethylene, polypropylene and PVC, polyester and polyamide fibres [NICNAS, 2009].
Main article groups	Polyethylene and polypropylene: injection moulded and blow moulded plastic products PVC: calendared film and cast PVC plastisol [NICNAS, 2009]. Polyester and polyamide fabrics [NICNAS, 2009]. Plastic end products using triclosan additives include various household moulded plastic products including: • Food storage containers; • Wheelie bins; • Toilet seats; • Toilet tidy sets; • PVC carpet backing; • Swimming pool liners; • Toothbrushes; and • Pet accessories such as litter trays, food bowls, and Frisbees. [NINCAS, 2009].

Substance	Triclosan $C_{12}H_7Cl_3O2$
Potential for release from plastics	The substance is not chemically bound, but is assessed as semivolatile (Molecular weight: 290 g/mol; vapour pressure: 4 x 10 –6 mm Hg (4 x 10 –4 Pa) at 20 °C, melting point: 56 – 58 °C, boiling point: 374 °C, log K_{oc}: 3.34 – 4.67) and should be assumed to migrate but fairly slow due to the high boiling point and probably not from a wet surface unless the water is basic (due to the phenolic hydroxyl group present).
Potential for exposure of consumers	As the triclosan might be added to a diverse number of consumers products like toys and toothbrushes, floor wax emulsions, polyethylene, polyurethane, polypropylene and other materials e.g. textiles there will be a risk for consumers to be exposed to the substance alone because it is used in many applications. However according to the Danish EPA [Danish EPA 2006] 99 % of the consumption in Denmark in the period 2000-2004 (3.9 – 1.8 t/year) is in cosmetic products including pasta for tooth brushing and deodorants, so the exposure from plastics is assumed negligible.
Fate of the substance by recycling	The substance is judged to stay in the plastic by mechanical recycling due to the high boiling point. To the extent products containing the substance are directed to incineration the content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	NICNAS (2009). Triclosan. Priority existing chemical, Assessment report no. 30. National industrial chemicals notification and assessment scheme. Australian Government. http://www.nicnas.gov.au/publications/car/pec/pec30/pec_30_full_report_pdf.pdf Danish EPA (2006). Kortlægning af kemiske stoffer i forbrugerprodukter, 73, 2006. Danish Environmental Protection Agency.

3.3 Blowing agents

Blowing agents create the cellular structures in plastic foams and can be divided into physical and chemical blowing agents. Physical blowing agents function by evaporation from the liquid phase or by expansion of a gas under pressure. CFC-gasses and HCFC-gasses, and hydrocarbons as propane, butane and pentane are examples of physical blowing agents and are or have typically been used for insulating plastic product as PU insulation foam, EPS and XPS. Carbon monooxide is also used in combination with de other gasses/liquids.

The chemical blowing agents are designed to release the gas close to the process temperatures. It is important that the gas is released slowly and preferably as a heat consuming process (endotherm). Typical blowing agents are azocarbonamider and other hydrazinderivatives organic substances containing nitrogen that by heating will release nitrogen as a blowing gas in the foaming process [Plastteknologi 2000].

As the amount of blowing agent used depends on the density of the foam to be obtained and the potential gas production of the blowing agent no general rules regarding the used can be presented. The amount present in the final product should optimally be zero, but in reality small amounts of residues may be present.

Chloromethane and fluorinated greenhouse gases migrate easily and will generally diffuse out of the products rather quickly from foam with open cells. For foam with closed cells and the foam locked between metal sheets etc. the diffusion will be limited, as experience shows that even e.g. old district heating pipes, in which the media tube is operated at about 90 °C, still contains a significant quantity of CFC.

C,C'-azodi(formamide) (ADCA) is converted by the release of nitrogen during the foaming process, but residues of ADCA may be present in the final products.

The fate by recycling depends heavily on the plastic material in question. For materials which can be subject to mechanical recycling (fragmentation/remelting – e.g. PVC, PE, PP and PS) ADCA will remain in the products, while other blowing agents likely will evaporate completely. Materials as PUR, phenolic foam and epoxy can only be recycled by incineration or by feedstock recycling. In both cases all residues of the blowing agents will be decomposed.

3.3.1 C,C'-azodi(formamide) (ADCA)

Substance	C,C'-azodi(formamide) (ADCA $C_2H_4N_2O_2$) ; Diazene-1,2-dicarboxamide
CAS Number	123-77-3; 97707-96-5
Justification	Candidate list, Registry of intentions (SVHC).
Function	Foaming agent.
Relevant types of plastics	PVC, polyethylene and epoxy resins.
Main article groups	Foamed/cell products inclusive of plastisols, carpets and epoxy structural foam.
Potential for release from plastics	Molecular weight: 116.1g/mol, no melting point, but decomposition at >200°C, vapour pressure: 2 x 10^{-8}Pa, water solubility: 33 mg/l at 20°C, $\log_{10}P_{ow}$ < 1.0 [Annex XV dossier]. Only present in plastic if the substance is not 100% converted to the blowing gases nitrogen, carbon monoxide, carbon dioxide and ammonia. As the gasses are formed at 200 °C, residues of the substance may be present if the decomposition temperature is not reached during processing throughout the plastic product.

Substance	C,C'-azodi(formamide) (ADCA $C_2H_4N_2O_2$) ; Diazene-1,2-dicarboxamide
Potential for exposure of consumers	The substance has been banned in materials in contact with food in EU since august 2005. Based on this ban it is judged that there might be left residues in other consumer products. Due to its very polar structure it is judged to be very water-soluble and might migrate easily to water, water solutions or by skin contact.
Fate of the substance by recycling	For plastics which are recycled at temperatures below 200°C (e.g. flexible PVC) the substance may be present in the recycled materials. In other cases it will decompose. Epoxy can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	Annex XV – ADCA. C,C'-azodi(formamide). http://echa.europa.eu/documents/10162/d9e11c88-481a-47a9-8fff-915b48086ddb

3.3.2 Chloromethane, methyl chloride

Substance	Chloromethane, methyl chloride CH_3Cl
CAS Number	74-87-3
Justification	List of CMR-substances in toy.
Function	Blowing/foaming agent.
Relevant types of plastics	PS-, PE-,PP-,PUR-,Phenol resin-, acetylcellulose- foams.
Main article groups	Foamed, cell plastics.
Potential for release from plastics	Molecular weight: 50.49 g/mol, melting point: - 97.4°C, boiling point: -23.8°C, vapour pressure: 506 hPa at 20°C, water solubility: 5.325 mg/l [Wikipedia 2014]. Low boiling gas (boiling point at minus 23.8°C) assumed to evaporate during production and use of the products. It is not known whether methyl chloride is still used as blowing agent on the European marked, but it is judged that the risk is low.
Potential for exposure of consumers	The low boiling point of the substance means that it will evaporate rapidly from the blown products. Only shortly after production there is judged to be a risk for exposure. The substance will probably be converted to hydrochloric acid and methanol in presence of water.
Fate of the substance by recycling	For plastics which can be subject to mechanical recycling (e.g. PS, PE, and PP) residues of the blowing agent will likely evaporate completely during the recycling process. Polyurethane and phenolic foam can only be recycled by incineration or by feedstock recycling. In both cases chloromethane will be decomposed. In Denmark only incineration is practised. The content of chlorine may add to the formation of dioxins and HCl in the chimney system.
References	Wikipedia (2014). Chloromethane. http://en.wikipedia.org/wiki/Chloromethane (April 2014)

3.3.3 Fluorinated greenhouse gasses (HFCs, PFCs and SF6)

Substance	HFCs, PFCs and SF6
CAS Number	811-97-2 (HFC 134a); 354-33-6 (HFC 125); 420-46-2 (HFC 143a); 75-37-6 (HFC 152a); 460-73-1 (HFC 245fa); 406-58-6 (HFC 365mfc); 75-73-0 (CF4); 76-16-4 (C2F6); 76-19-7 (C3F8); 2551-62-4 (SF6) etc.
Justification	Danish list of undesired substances.

Substance	HFCs, PFCs and SF6
Function	Blowing agent.
Relevant types of plastics	Polyurethane foam (HFC 134a, HFC 245fa, and HFC 365mfc), polystyrene foam (HFC 134a, HFC 152a) and phenolic foam (HFC-365mfc).
Main article groups	In Denmark today fluorinated greenhouse gasses are banned as blowing agent but until about 2002 they were used for rigid polyurethane foam for insulation purposes (refrigerators, freezers, insulation panels, district heating pipes). Still used outside Denmark as blowing agent in polyurethane foam, polystyrene foam and phenolic foam (the precise applications are not known) [Hansen et al 2014].
Potential for release from plastics	Data for HFC 134a (serves as example): Molecular weight: 102.03 g/mol, melting point: -101°C, boiling point: -26°C, vapour pressure: 630 kPa at 25°C, water solubility: none, log P_{ow}: 1.06 [Barker et al, 1998]. The substances are not chemical bound and will diffuse more or less fast depending on the temperature for use and the product. In many cases the product will be a sandwich construction, e.g. freezers or insulating panels, in which the foam is placed between sheets of metal or plastic that significantly reduces the rate of diffusion.
Potential for exposure of consumers	Exposure depends on the products in question. Generally the low boiling point of the substance means that it will evaporate rapidly from the blown products. Only shortly after production there is judged to be a risk for exposure. For products in which the foam is placed between sheets of metal or plastics (e.g. most or all refrigerators and freezers manufactured up till about 2002 and still in use) consumers will be exposed to HFCs slowly evaporating. The toxicity of these substances are however very low [Hansen et al 2014]. New products manufactured outside Denmark and imported to Denmark may result in higher exposure.
Fate of the substance by recycling	Polyurethane and phenolic foam can only be recycled by incineration or by feedstock recycling. In both cases HFCs will be decomposed. In Denmark only incineration is practised. By incineration fluor acid will be generated. The acid is generally neutralised in the filter unit of the plant. Polystyrene foam can be subject to mechanical recycling (fragmentation/remelting). In this case residues of the blowing agent will likely evaporate completely during the recycling process.
References	Barker P, Cary R and Dobson S (1998): Concise International Chemical Assessment Document 11: 1,1,1,2-Tetrafluoroethane. http://apps.who.int/iris/bitstream/10665/42125/1/9241530111.pdf Hansen E., Pedersen P.H., Christensen F.M., Feilberg K.L. (2014). Review and survey of selected Fluorinated greenhouse gases. A report under the LOUS review project. Danish Environmental Protection Agency. 2. Draft version.

3.4 Heavy metal based colorants, stabilisers and catalysts

Some heavy metals form complexes with strong colours and have been used to dye polymers. Heavy metals, such as lead, tin, cadmium and zinc are also used as stabilisers for PVC [Subramanian 2013].

Typical amount of heavy metal based colorants in plastic products is 0.01-10 % (w/w) [Hansen et al, 2013].

Generally the substances are strongly bound in the plastic materials and will not migrate. The exposure to consumers must therefore be considered low. By mechanical recycling the substances will be present in the plastic being recycled and thus integrated in new products. But mercury is the exception to this, as mercury will migrate and evaporate. Mercury is furthermore used only in polyurethane which can only be recycled by feedstock recycling or by energy recovering (incineration). The fate of mercury by feed stock recycling is not known.

3.4.1 Cadmium and cadmium compounds

Substance	Cadmium and cadmium compounds
CAS Number	7440-43-9, 10108-64-2, 542-83-6, 7790-79-6, 4464-23-7, 7790-80-9, 17010-21-8, 1306-19-0, 10124-36-4, 1306-23-6 etc.
Justification	Danish list of undesired substances; Norwegian priority list: Candidate list; Registry of intentions (CLP, restriction); List of CMR-substances in toy.
Function	Pigment - colours include yellow, orange, red and in principle all others colours as green, brown, beige etc. that may be based on yellow and red. Cadmium sulphide and cadmium selenide are the main substances used as pigments. [MST 1980]. Heat and UV stabilizer in PVC and similar materials [MST 1980]. The starting material is cadmium oxide for pigments and PVC stabilisers, but also the cadmium metal can be used for making the stabiliser [EU, 2007].
Relevant types of plastics	Cadmium pigments may be used in all types of plastics being coloured. Cadmium stabilizers are used mainly in PVC.
Main article groups	Cadmium pigments are/were used mainly in quality products with a long lifetime. Cadmium pigments are/were used anywhere the colours in question are needed, and in particular for safety purposes. [Hansen et al 2005]. Cadmium stabilizers were used mainly for outdoor purposes (doors, windows, crystal clear roof windows) [Hansen et al 2005].
Potential for release from plastics	Cadmium and cadmium compounds will be solid bound in plastics. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	Cadmium pigments and stabilisers are today banned in EU. So exposure will only happen from products produced before the ban or illegal products sold on the market. Many items containing cadmium are, however, still in use (e.g. old plastic building toy bricks, windows frames etc.). Exposure to the substance from cadmium pigments and stabilizers is considered unlikely due to the low concentration of the pigments in the plastic. However it is possible that the consumers can be exposed to cadmium from plastic items (e.g. old kitchen items or windows) exposed to acidic liquids (acetic acid, HCl).

Substance	Cadmium and cadmium compounds
Fate of the substance by recycling	Cadmium pigments and stabilisers will remain in the plastic by mechanical recycling as they are solid bound.
References	EU (2007). European Union Risk Assessment Report. Cadmium metal. http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/cdmetalreport303.pdf Hansen, E.; Lassen, C.; Stuer-Lauridsen, F.; Kjølholt, J. (2002). Heavy metals in waste. EU Commission, DG Environment, Brussels 2002. Hansen, E.; Lassen, C.; Maxson, P. (2005). RoHS substances (Hg, Pb, Cr(VI), Cd, PBB and PBDE) in electronic equipment in Belgium. Directorate-General Environment. Federal Public Service Health, Food Chain Safety and Environment. Belgium. MST (1980). Cadmiumforurening. En redegørelse om anvendelse, forekomst og skadevirkninger af cadmium i Danmark. Miljøstyrelsen, København. ATSDR 2012d. Toxicological Profile for Cadmium. Agency for Toxic Substances and Disease Registry. U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp

3.4.2 Chromium and chromium compounds

Substance	Chromium and chromium compounds - see also section 3.4.3, 3.4.6-3.4.8 and 3.11.6
CAS Number	1333-82-0, 7778-50-9, 7789-09-5, 10588-01-9, 7789-00-6, 13765-19-0, 7789-06-2, 24613-89-6, 12656-85-8, 1344-37-2, 1308-38-9, 7738-94-5, 7758-97-6, 7775-11-3, 7789-12-0, 7789-09-5, 10294-40-3, 13530-68-2, 13530-65-9,14977-61-8, 37300-23-5, 11103-86-9, 18540-29-7 etc.
Justification	Norwegian priority list; Candidate list; List of CMR substances in toy; Registry of intentions (SVHC, restriction).
Function	Catalyst for production of plastics (chromium trioxide - see section 3.16), component in pigments (yellow, red and green colours - see section 3.25-3.28) [Annex XV report; Hoffmann et al 2002].
Relevant types of plastics	PVC, polyethylene, polypropylene and other non-specified plastics [Annex XV report; Hofmann et al 2002].
Main article groups	All articles, where a need for yellow, red and green colours exist.
Potential for release from plastics	Chromium and chromium compounds is solid bound in plastics. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	Chromium can be found in many consumer products such as: wood treated with copper dichromate, leather tanned with chromium sulphate and stainless steel cookware. The exposure to the consumers from plastic coloured with chromium based pigments is judged insignificant. The same is the case for the chromium used as catalyst as catalysts are used in very low concentrations.
Fate of the substance by recycling	Chromium pigments will stay in the plastic by mechanical recycling as they are solid bound.

Substance	Chromium and chromium compounds - see also section 3.4.3, 3.4.6-3.4.8 and 3.11.6
References	Annex XV report. Proposal for a restriction. http://echa.europa.eu/documents/10162/4d88d444-4b8b-48ab-9c11-6e74819e047c Hoffmann L., Grinderslev M., Helweg C., Rasmussen J.O. (2002). Massestrømsanalyse af chrom og chromforbindelser. Miljøprojekt Nr. 738. Miljøstyrelsen. Swedish Chemicals Agency. (2007). Varuguiden. (Guide for articles) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx. ATSDR 2012e. Toxicological Profile for chromium. Agency for Toxic Substances and Disease Registr. U.S. Dept. of Health and Human Services, Public Health Service. www.atsdr.cde./toxprofiles/index.asp

3.4.3 Chromium trioxide

Substance	Chromium trioxide - see also section 3.4.2
CAS Number	1333-82-0
Justification	Norwegian priority list; Candidate list; Registry of intentions (SVHC); List of CMR-substances in toy.
Function	Catalyst for production of plastics. Intermediate for pigment manufacture [Annex XV report].
Relevant types of plastics	Polyethylene and other plastics [Annex XV report].
Main article groups	Not specified - probably many different products.
Potential for release from plastics	Probably solid bound and may only be released by wear and tear.
Potential for exposure of consumers	No potential risk for exposure as chromium trioxide only is used as catalyst in low amount for the polymerisation of plastics and as intermediate for pigments which is solid bound in the plastic.
Fate of the substance by recycling	Chromium compounds will stay in the plastic by mechanical recycling as they are solid bound.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_chromium-trioxide_en.pdf

3.4.4 Cobalt(II) diacetate

Substance	Cobalt(II) diacetate
CAS Number	71-48-7
Justification	Candidate list; Registry of intentions (SVHC); CMR.

Substance	Cobalt(II) diacetate
Function	Pigment for tinting PET a light blue colour [Annex XV report]. Note: This use is being phased out according to information from the Committee of PET manufacturers in Europe [ECHA, 2011]. *Other plastic related function:* Catalyst e.g. in the production of Purified Terephthalate Acid (an intermediate for the manufacture of polyester fibre) – by far the main use [Annex XV report].
Relevant types of plastics	Polyester (PET).
Main article groups	PET bottles.
Potential for release from plastics	Molecular weight: 177.02g/mol, melting/freezing point: No data for anhydrous form (loses 4 H_2O at 140˚C for tetrahydrate form), water solubility: Readily soluble [Annex XV report 2010]. Probably solid binding in plastics. The pigment should not be assumed to migrate. Release only by wear and tear of plastic materials. The potential for release from plastics is likely to be insignificant.
Potential for exposure of consumers	The substance is easily soluble in water and might migrate from blue PET bottles into the liquid (e.g. mineral water) contained in the bottles, but no data is available in the Annex XV report to support this judgement. The reason might be that the salt is solid bound in the PET. Anyhow the manufacturers of PET bottles will out phase the substance from use in PET bottles.
Fate of the substance by recycling	It is judged that by mechanical recycling the substance (and colour) will remain in the plastic, but a small amount might be removed in the washing step due to the high solubility in water.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_netherlands_cmr_co-diacetate_en.pdf ECHA (2011). Background document for cobalt (II) diacetate. http://echa.europa.eu/documents/10162/e8682070-93db-40d4-846b-214daf89719e Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014.

3.4.5 Lead and lead compounds

Substance	Lead and lead compounds - see also section 3.4.6-3.4.8.
CAS Number	75-74-1, 78-00-2, 301-04-2, 1072-35-1, 1314-41-6, 1317-36-8, 1319-46-6, 1335-32-6, 1344-37-2, 6838-85-3, 7428-48-0, 7439-92-1, 7446-14-2, 7446-27-7, 7758-95-4, 7758-97-6, 12141-20-7, 12656-85-8, 13424-46-9, 13453-65-1, 15245-44-0, 16038-76-9,16183-12-3, 17570-76-2, 24824-71-3, 25808-74-6, 53807-64-0, 61790-14-5, etc.
Justification	Danish list of undesired substances; Candidate list; Norwegian priority list; List of CMR-substances in toy; Registry of intentions (SVHC, restriction).
Function	Heat and UV stabiliser for PVC (50% of all stabilisers used for PVC), pigments [Hansen et al, 2005; PVC, 2012].
Relevant types of plastics	Lead pigments may be used in all types of plastics being coloured. Lead stabilizers are used in PVC.

Substance	Lead and lead compounds - see also section 3.4.6-3.4.8.
Main article groups	Lead pigments may be used in all products where the colours provided are required. The colours available include yellow (lead chromates), orange, and red (mixtures of lead chromates/molybdates) and in fact all other colours like green, brown, beige, etc. that may be based on yellow or red. [Hansen et al 2005]. Lead stabilisers are dominantly used for pipes, gutters, outdoor products inclusive of roofs, windows and doors besides electrical cables and wires [Hansen et al 2005]. Regulated in plastic since 2001 in Denmark and implemented in 2003. The limit value is 100 mg/kg. EU also has set limits in ELV and RoHS directives and PVC producers in EU expect total substitution in 2015. Based on a restriction proposal a limit for lead in articles that can be mouthed by children is expected [WTO 2014].
Potential for release from plastics	The substance is solid bound. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	The most likely source of exposure is ingestion of contaminated food and drinking water. Exposure from lead in plastics either as a stabilizer or as a colour pigment is low. Release might happen in acidic environment and analysis standards exist which can be used for assessing the risk under these environmental conditions. Due to the ban in Denmark the risk for exposure is judged to be insignificant.
Fate of the substance by recycling	Lead substances will remain in the plastic during mechanical recycling as it is solid bound.
References	ATSDR 2012f. Toxicological Profile for lead. Agency for Toxic Substances and Disease Registry. U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp Hansen, E.; Lassen, C.; Stuer-Lauridsen, F.; Kjølholt, J. (2002). Heavy metals in waste. EU Commission, DG Environment, Brussels 2002. Hansen, E.; Lassen, C.; Maxson, P. (2005). RoHS substances (Hg, Pb, Cr(VI), Cd, PBB and PBDE) in electronic equipment in Belgium. Directorate-General Environment. Federal Public Service Health, Food Chain Safety and Environment. Belgium. PVC (2012). Lead stabilisers. webpage: http://www.pvc.org/en/p/lead-stabilisers Swedish Chemicals Agency. (2007). Varuguiden. (Guide for articles) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx WTO [2014]. https://members.wto.org/crnattachments/2014/tbt/eec/14_4233_01_e.pdf

3.4.6 Lead chromate

Substance	Lead chromate - see also section 3.4.5
CAS Number	7758-97-6
Justification	Norwegian priority list; Candidate list; Registry of intentions (SVHC); List of CMR substances in toy.
Function	Pigment/used in manufacturing of other lead chromate pigments [Annex XV report; Zweifel, 2001]. Provides green-yellow to red-yellow colours [Annex XV report].

Substance	Lead chromate - see also section 3.4.5
Relevant types of plastics	Used in plastic in all kinds of application [Zweifel, 2001].
Main article groups	Used in plastic in all kinds of application [Zweifel, 2001].
Potential for release from plastics	Molecular weight: 323.18 g/mol, melting/freezing point: 844 °C, water solubility (two values found): 0.0000058 g/100 ml at 25°C and 0.2 mg/l [Annex XV report 2009]. The substance is solid bound. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	Exposure from lead in plastics is low. Release might happen in acidic environment and analysis standards exist which can be used for assessing the risk under these environmental conditions. Due to the ban in Denmark the risk for exposure is judged to be insignificant.
Fate of the substance by recycling	Lead chromate will remain in the plastic during mechanical recycling.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_france_cmr_lead_chromate_20090831_en.pdf Zweifel, H. (2001). Plastics additives handbook. 5th edition. Carl Hanser Verlag, Munich.

3.4.7 Lead chromate molybdate sulphate red (C.I. Pigment Red 104)

Substance	Lead chromate molybdate sulphate red (C.I. Pigment Red 104) - see also section 3.4.5
CAS Number	12656-85-8
Justification	Norwegian priority list; Candidate list; Registry of intentions (SVHC); List of CMR substances in toy.
Function	Pigment (red). The plastic industry is the largest consumer of C.I. Pigment Red 104 [Annex XV dossier].
Relevant types of plastics	All types of plastics, where red pigments are used.
Main article groups	All types of plastic products, where red pigments are used.
Potential for release from plastics	The substance is solid bound. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	The substance is composed by 69-80% lead chromate (323.2 g/mol), 9-15 % lead sulphate (303.4 g/mol) and 3-7 % lead molybdate (367.1 g/mol). Melting/freezing point: > 800 °C, vapour pressure: insignificant, water solubility: < 0.01 mg/l at 20°C [Annex XV dossier 2009]. Exposure from lead in plastics is low. Release might happen in acidic environment and analysis standards exist which can be used for assessing the risk under these environmental conditions. Due to the ban in Denmark the risk for exposure is judged to be insignificant.
Fate of the substance by recycling	The lead substance will remain in the plastic during mechanical recycling.

Substance	Lead chromate molybdate sulphate red (C.I. Pigment Red 104) - see also section 3.4.5
References	Annex XV dossier http://echa.europa.eu/documents/10162/13640/svhc_axvrep_france_cmr_lead_chromate_sulfate_red_20090831_en.pdf Swedish Chemicals Agency (2007). Varuguiden.(Article guide) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx.

3.4.8 Lead sulfochromate yellow (C.I. Pigment Yellow 34)

Substance	Lead sulfochromate yellow (C.I. Pigment Yellow 34) - see also section 3.4.5
CAS Number	1344-37-2
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (SVHC); List of CMR substances in toy.
Function	Pigment (yellow).
Relevant types of plastics	Mainly HDPE, LDPE, PVC [Zweifel, 2001], cellulose acetate [Annex XV] and polypropylene [Swedish Chemicals Agency, 2007]. In reality all types of plastics, where yellow pigments are used.
Main article groups	In reality all types of plastics, where yellow pigments are used.
Potential for release from plastics	The substance is solid bound. Release is related to wear and tear of products (e.g. if a plastic window is grinded before painting). Existing information does not allow quantification. However, the quantity released can be assessed as small compared to the quantity present in the product.
Potential for exposure of consumers	The substance is composed by 40-90% lead chromate (323.2 g/mol) and 20-50 % lead sulphate (303.4 g/mol). Melting/freezing point: 840 °C, vapour pressure: insignificant, water solubility: < 0.01 mg/l at 20°C [Annex XV dossier 2009]. Exposure from lead in plastics is low. Release might happen in acidic environment and analysis standards exist which can be used for assessing the risk under these environmental conditions. Due to the ban in Denmark the risk for exposure is judged to be insignificant.
Fate of the substance by recycling	The lead substance will remain in the plastic during material recycling.
References	Annex XV dossier http://echa.europa.eu/documents/10162/13640/svhc_axvrep_france_cmr_lead_sulfochromate_yellow_20090831_en.pdf Swedish Chemicals Agency (2007). Varuguiden. (Article guide) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx. Zweifel, H. (2001). Plastics additives handbook. 5th edition. Carl Hanser Verlag, Munich.

3.4.9 Mercury and mercury compounds

Substance	Mercury and mercury compounds

Substance	Mercury and mercury compounds
CAS Number	55-68-5, 62-38-4, 100-57-2, 123-88-6, 593-74-8, 627-44-1, 628-86-4, 1335-31-5, 1344-48-5, 7439-97-6, 7487-94-7, 7546-30-7, 7783-35-9, 8003-05-2, 10112-91-1, 62-38-4, 103-27-5, 13302-00-6, 13864-38-5, 26545-49-3
Justification	Danish list of undesired substances; Norwegian priority list; Registry of intentions (CLP, restriction); CMR.
Function	Catalyst [UNEP, 2011].
Relevant types of plastics	Polyurethane [UNEP, 2011].
Main article groups	Examples of mercury catalyst based polyurethanes in use today, for example in gaskets and seals, as encapsulant for electronic assemblies, in film and television props, in vibration dampers, for clear polyurethane on labels, water resistant coatings and concrete sealants, for boat repair and repair on conveyor belts, in rollers on swivel chairs and roller skates and in shoe soles. It has also been used in flooring [UNEP, 2011].
Potential for release from plastics	The substances are not chemically bound and will migrate. Elemental mercury will vaporise from the plastic material, e.g. flooring [Lassen et all, 2008]. The use of mercury in products on the Danish market has in principle been banned in plastics since 1994. At that time the allowed limit was 50 ppm. In 2003 it was changed to 100 ppm. The use of mercury as a catalyst in PU was first generally recognized in 2005. This use is banned in Denmark but not in other EU countries and globally.
Potential for exposure of consumers	Mercury present in polyurethane products should be expected slowly to evaporate. Consumers may be exposed by inhalation and skin contact but actual risk is likely small. However, measurements confirming this assessment are not available.
Fate of the substance by recycling	Polyurethane can only be recycled by feed stock recycling or energy recovering as practised in Denmark. Most mercury has likely evaporated by then. The fate of mercury by feed stock recycling is not known. Polyurethane products containing mercury will in Denmark dominantly be directed to incineration.
References	Annex XV restriction report – phenylmercury. Phenylmercury acetate, phenylmercury propionate, phenylmercury 2-ethylhexanoate, phenylmercuric octanoate, phenylmercury neodecanoate. http://enfo.agt.bme.hu/drupal/sites/default/files/annex%20XV%20phenylmercury.pdf Lassen C., Andersen B.H., Maag J., Maxson P. (2008). Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society. European Commission Directorate-General Environment, Brussel. UNEP. 2011. Intergovernmental negotiating committee to prepare a global legally binding instrument on mercury. Third session Nairobi, 31 October–4 November 2011. Submission by the Government of Norway on processes using mercury, particularly catalysts in the production of polymers and chemicals. http://www.zeromercury.org/phocadownload/Developments_at_UNEP_level/INC3/CRP8_Norway_processes.pdf Weinberg, J. (2010). An NGO introduction to mercury pollution. International POPs Elimination Network (IPEN). http://www.ipen.org/ipenweb/documents/book/ipen%20mercury%20booklet_s.pdf

3.5 Flame retardants

Plastics have relatively high flammability and may produce corrosive or toxic smoke during combustion. To increase the resistance towards fire flame retardants are often added into the organic polymers.

The flame retardants vary by action [Subramanian 2013]:

- Degradation where no volatile gases are produced;
- Removal of critical radicals so that flame can be prevented or removed;
- Removal of heat generation by the endothermic reactions;
- Formation of thermally insulating char layer on the surface of the polymer.

Typical amount of brominated flame retardants in plastic products is 12-18 % (w/w) [Hansen et all, 2013].

According to [US EPA, 2014] the typical loading levels for fire retardants are as tabulated below:

Type of flame-retardant	Loading (wt %)
Bromine-based	2-25 %
Aluminium Hydroxide	13-60 %
Magnesium Hydroxide	53-60 %
Chlorophosphates	9-10 %
Organophosphorus	5-30 %

Migration habits differ strongly between the substances. Some substances and in particular most brominated flame retardants migrate relatively easily and may thus result in significant exposure of consumers.

Other substances such as the reactive brominated flame retardants are, however, strongly bound in plastic material and will not migrate to any significant extent. They will therefore not result in significant exposure to users of plastic products.

Alternatives to existing flame retardants constitute a relative large part of the group. The alternatives are generally less investigated and are characterised by lack of knowledge regarding both applications and fate in the products as well as by subsequent recycling activities.

The fate by recycling depends heavily on the plastic material in question. For materials which can be subject to mechanical recycling (fragmentation/remelting – e.g. PVC, PE, PP and PS) flameretardants will remain in the materials being recycled. Materials as PUR and epoxy can only be recycled by incineration or by feedstock recycling. In both cases all residues of the flame retardants will decompose with the formation of degradation products.

It should be noted that Chlorinated Paraffin's (SCCP and MCCP – see section 3.9.3 and 3.9.4) will also function as flame retardants besides their function as plasticiser.

3.5.1 Boric acid

Substance	Boric acid (H_3BO_3)
CAS Number	10043-35-3, 11113-50-1
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (CLP, SVHC)); CMR.

Substance	Boric acid (H_3BO_3)
Function	Boric acid can be used as flame retardant for polystyrene beads [Weil and Litchi, 2009]. Component (39-48 %) in zinc borate flame retardant [Murphy, 2001]. Component (not further defined) in silly putty toys [Annex XV dossier].
Relevant types of plastics	Polystyrene beads [Weil and Litchi, 2009], PVC [Murphy, 2001], Silly putty (synthetic rubber) [Silly putty 2012].
Main article groups	Polystyrene foam [Weil and Litchi, 2009]; PVC leather cloth, foil, calendaring film and cable [Murphy, 2001], and Silly putty toy [Annex XV dossier].
Potential for release from plastics	Molecular weight: 61.83 g/mol, melting point: No melting point can be defined in the range 25- 1000°C due to the decomposition of the substance, water solubility : 47.2 g/l at 20°C, log K_{ow}: -1.09 ± 0.16 (22± 1°C) [Annex XV dossier 2010]. Zinc borates will be solid bound, while boric acid may migrate. Not solid bound in silly putty, will migrate at least partly. [Nilsson, 2012].
Potential for exposure of consumers	If used in polystyrene as flame-retardant it is judged that the consumer will not be exposed as the substance will be present in polystyrene used for insulation purposes and the substance will not evaporate. Exposure might happen to workers (professionals). Uses as PVC leather cloth, foil, calendaring film and silly putty toy may lead to exposure of children and adults.
Fate of the substance by recycling	By mechanical recycling the substance will remain in the plastic as it will not evaporate. However if the temperature rise to more than 100° C, water (H_2O) will be split of and HBO_2 formed. By energy recovery in incineration plants the substance will be converted to B_2O_3 and catched by the filters.
References	Annex XV dossier 2010. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_boric_acid_en.pdf Murphy, J. (2001). Additives for plastics handbook. Elsevier Science Ltd. oxford, New York, Tokyo. Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014. Silly putty (2012). http://www.chem.umn.edu/outreach/Sillyputty.html (Dec 2012). Wiel, E.D., Levchik, S.V. (2009). Flame retardants for plastics and textiles. Practical applications. Carl Hanser Verlag, Munich.

3.5.2 Brominated flame retardants

Substance	Brominated flame retardants - see also section 3.5.3
CAS Number	32534-81-9 (PeBDE), 32536-52-0 (OBDE), 1163-19-5 (DBDE), 25637-99-4 (HBCDD; 79-94-7(TBBPA), 3194-55-6, 134-51-7, 134237-52-8, etc. Some of the brominated flame retardants are covered by specific sections.
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (CLP, SVHC); CMR.

Function	Flame retardant [Zweifel, 2001].
Relevant types of plastics	ABS, EPS, HIPS, polyamides, PBT, polyethylene, polypropylene, epoxy, unsaturated polyester, polyurethane [Zweifel, 2001].
Main article groups	Brominated flame retardants are frequently used in: • 'Brown' goods such as television sets, computer hardware housings and monitors, etc.; • in polystyrene foams (e.g. see also hexabromocyclododecane(HBCDD)); • EPS and XPS: Insulation boards in buildings, against frost heaves of road and railway embankments, in transport vehicles; EPS: Packaging material (minor use and not in food packaging). HIPS: Electric housings for VCR; Electrical and electronic equipment e.g. distribution boxes for electrical lines; Video cassette housing. • Polymer dispersions in textile coating: Upholstery fabric; Bed mattress ticking; Flat and pile upholstered furniture (residential and commercial furniture); Upholstery seatings in transportation, draperies, and wall coverings; Interior textiles e.g. roller blinds; Automobile interior textiles [Annex XV].
Potential for release from plastics	Flame retardants can be either reactive (chemically bound in the material) or additive (not chemically bound in the material) [Zweifel, 2001]. While TBBPA generally are used as a reactive flame retardant, the other brominated flame retardants focused on here are additive flame retardants [Lassen et al., 1999]. Additive flame retardants will migrate. For thermoplastics non-reactive flame retardants (additive) are usually used, while reactive flame retardants are normally used for thermosetting plastics (epoxy, unsaturated polyester and polyurethane) [Frisk et al, 2003; Zweifel, 2001]. Additive flame retardants can be released from the plastic material since they are not chemically bound. For the reactive flame retardant release is limited since they are chemically bound within the polymer. [Frisk et al, 2003].
Potential for exposure of consumers	Polybrominated biphenyls and diphenylethers have been banned or restricted to <0.1% in new electrical and electronic products according to EU ROHS directive since 2006, but they may still be present in a number of products still in service for a considerable time. Consumers can thus be exposed to the banned substances from inhalation of either emitted particles with the condensed flame retardants or the flame-retardant themselves for a considerable time. Marketing and use of HBCDD requires special authorisation according to the REACH-regulation from 21 August 2015. For reactive flame retardants potential for exposure of consumers is limited as they are chemically bound within the polymer.
Fate of the substance by recycling	Brominated flame retardants will probably remain in the recycled materials by mechanical recycling. By energy recovery in incineration plants the substance will be decomposed.
References	Frisk, P.R., Girling, A.E., Widely, R.J. (2003). Prioritisation of flame retardants for environmental risk assessment. UK EPA. http://ec.europa.eu/environment/waste/stakeholders/industry_assoc/ebfrip/annex2.pdf

	Lassen C., Løkke S., Andersen L.I. (1999). Brominated Flame Retardants - Substance Flow Analysis and Assessment of Alternatives Environmental Project **Nr. 494/**1999. The Danish Environmental Protection Agency Zweifel, H. (2001). Plastics additives handbook. 5th edition. Carl Hanser Verlag, Munich.

3.5.3 Hexabromocyclododecane (HBCDD) and all major diastereoisomers

Substance	**Hexabromocyclododecane (HBCDD) and all major diastereoisomers identified - Alpha-hexabromocyclododecane, Beta-hexabromocyclododecane, Gamma-hexabromocyclododecane - see also section 3.5.2)**
CAS Number	25637-99-4; 3194-55-6; 134237-50-6; 134237-51-7; 134237-52-8 (included in the group of brominated flame retardants)
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (SVHC); CMR.
Function	Flame retardant
Relevant types of plastics	Expandable polystyrene (EPS), extruded polystyrene (XPS), High impact polystyrene (HIPS), polymer dispersions on cotton or cotton/synthetic blends [Annex XV dossier].
Main article groups	EPS and XPS: • Insulation boards in building constructions e.g. houses' walls, cellars and indoor ceilings and "inverted roofs" (outdoor) – main use; • Insulation boards against frost heaves of road and railway embankments – main use; • Insulation boards (against cold or warm) of transport vehicles e.g. lorries and caravans. EPS: Packaging material (minor use and not in food packaging). HIPS: • Electric housings for VCR; • Electrical and electronic equipment e.g. distribution boxes for electrical lines; • Video cassette housing. Polymer dispersions in textile coating: • Upholstery fabric; • Bed mattress ticking; • Flat and pile upholstered furniture (residential and commercial furniture); • Upholstery seatings in transportation, draperies, and wall coverings; • Interior textiles e.g. roller blinds; • Automobile interior textiles [Annex XV dossier].
Potential for release from plastics	The substance is not chemically bound and will migrate. Solid substance. Approximate boiling point: 172 – 205 °C (in average 190 °C), log $P_{o/w}$: 5.1 -5.6. Given sufficient time, a significant part of the substance will probably be released by migration to the surface followed by evaporation or removal by washing. Tear and wear will also take place.

Substance	Hexabromocyclododecane (HBCDD) and all major diastereoisomers identified - Alpha-hexabromocyclododecane, Beta-hexabromocyclododecane, Gamma-hexabromocyclododecane - see also section 3.5.2)
Potential for exposure of consumers	The main part (90 %) of HBCDD is used as flame retardant in polystyrene (PS). PS-containing HBCDD, in the form of Expanded PS (EPS) or Extruded PS (XPS), is mainly used as rigid thermal insulation panels/boards for buildings and for road and railway constructions to prevent frost heaves and provide a lightweight load-spreading construction material. HBCDD is also used to flameretarded textiles (for furniture, automobile interiors etc.) and in smaller quantities in High Impact PS (HIPS). (Annex XV dossier). Marketing and use of HBCDD requires special authorisation according to the REACH- regulation from 21 August 2015. Exposure to the consumers from electric and electronic equipment is possible because the flame retardants are used in places which get hot during service. Consumers can be exposed to the substances from inhalation of either emitted particles with the condensed flame retardants or the flame-retardant themselves by touching surfaces of relevant products.
Fate of the substance by recycling	By recycling some evaporation of HBCDD will likely take place but a significant part will remain in the recycled materials. By energy recovery in incineration plants the substance will be decomposed.
References	Annex XV dossier http://echa.europa.eu/documents/10162/3f5de199-8732-4881-aec6-730bf9499a36

3.5.4 Molybdenum trioxide

Substance	Molybdenum trioxide
CAS Number	1313-27-5
Justification	Danish list of undesired substances; CMR.
Function	Flame retardant.
Relevant types of plastics	Polyester, PVC [Canada 2009].
Main article groups	No information.
Potential for release from plastics	Solid bound. Melting point: 795 °C, boiling point: 1155 °C, solubility in water: 0.5 g /l. Water absorption in both polyester and PVC is low so it is judged that molybdenum trioxide will not migrate even if in contact with water.
Potential for exposure of consumers	It is judged that there is no risk for exposure.
Fate of the substance by recycling	The molybdenum will remain in the material by mechanical recycling and end in the slag by energy recovery by incineration
References	Canada (2009). Molybdenum trioxide. Office of Environmental Health Hazard Assessment. http://www.oehha.ca.gov/prop65/CRNR_notices/state_listing/prioritization_notices/pdf/Molydenumtrioxide.pdf ChemBlink.com; Online database of Chemicals. http://www.chemblink.com/products/1313-27-5.htm

3.5.5 Tris(2-chloroethyl)phosphate

Substance	Tris(2-chloroethyl)phosphate (TCEP)
CAS Number	115-96-8
Justification	Candidate list; Registry of intentions (SVHC); List of CMR substances;
Function	Plasticiser and viscosity regulator with flame retardant properties (for polyurethane, polyesters, polyvinyl chloride and other polymers), secondary plasticiser (for PVC), flame retardant (for paint and varnishes containing e.g. polyvinyl acetate) [Annex XV report].
Relevant types of plastics	Polyurethane, polyester, PVC, polyvinyl acetate [Annex XV], polymetamethylacrylate (PMMA), epoxy, polyamide, polycarbonate, polyurethane, thermoplastic polyester and unsaturated polyester [Swedish Chemicals Agency, 2007]. The main use of today is in the production of unsaturated polyester resins (80 %). Other fields of application are acrylic resins, adhesives and coatings. [EU, 2008].
Main article groups	Main industrial branches include furniture, the textile and the building industry (roof insulation); it is also used in the manufacture of cars, railways and aircrafts, and in paint and varnishes [Annex XV report; EU, 2008].
Potential for release from plastics	The compound is not chemically bound and may be regarded as semi-volatile (Molecular weight: 285.49 g/mol, no boiling point but decomposition at 320°C , vapour pressure: 43 Pa at 136.9 °C and 0.00114 Pa at 20°C (extrapolated)). Given sufficient time, the major part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	According to [ATSDR 2012a] routes of exposure for the consumers are oral - as the predominant route of exposure is through ingestion of contaminated food or water. Contaminated food is a result of the extensive use of phosphate esters in plastic. Exposure might also happen by inhalation of contaminated indoor air from fumes of plastic, adhesives, foams or electronics.
Fate of the substance by recycling	The TCEP will mainly remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed. The content of chlorine may add to dioxin and HCl formation in the chimney system.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_austria_cmr_tcep_20090831_en.pdf EU (2008). EU Risk Assessment Report. Tris(2-chloroethyl) phosphate, TCEP. CAS-No.: 115-96-8. http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tcepreport068.pdf Swedish Chemicals Agency (2007). Varuguiden.(Article guide) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx. ATSDR (2012a). Toxicological Profile for Phosphate Ester Flame Retardants. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp

3.5.6 Tris(2-chlor-1-methylethyl)phosphate (TCPP)

Substance	Tris(2-chlor-1-methylethyl)phosphate (TCPP)
CAS Number	13674-84-5
Justification	Danish list of undesired substances.
Function	Flame retardant.
Relevant types of plastics	PUR. No certain information on other plastics, but the substance may be used in the same articles as TCEP (see section 3.5.5), as TCPP is regarded as an alternative for TCEP [EU 2014].
Main article groups	Toys. No certain information on other articles, but the substance may be used in the same articles as TCEP (see section 3.5.5), as TCPP is regarded as an alternative for TCEP [EU 2014].
Potential for release from plastics	The compound is not chemically bound and may be regarded as semi-volatile. Given sufficient time, the major part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	Probably most exposure by inhalation indoor from foamed PUR products. No data found to support this.
Fate of the substance by recycling	Polyurethane can only be recycled by incineration or by feedstock recycling. In both cases the substance. In Denmark only incineration is practised. The content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	Larsen P.B., Andersen D. N., Lam H.R., Slothuus T. (2013). Survey of Tris(2-chloro-1-methylethyl)-phosphate. A LOUS review project. Danish Environmental Protection Agency. ATSDR (2012b). Toxicological Profile for Phosphate Ester Flame Retardants. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp. EU (2014). COMMISSION DIRECTIVE 2014/79/EU of 20 June 2014 amending Appendix C of Annex II to Directive 2009/48/EC of the European Parliament and of the Council on the safety of toys, as regards TCEP, TCPP and TDCP.

3.5.7 Bis(hexachlorocyclopentadieno) cyclooctane

Substance	Bis(hexachlorocyclopentadieno) cyclooctane
CAS Number	13560-89-9
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	CPE, engineering thermoplastics, HIPS, PE, PP, thermosets.
Main article groups	Electronics, wire cable, construction materials, waterborne emulsions & coatings.
Potential for release from plastics	The substance has a molecular weight of 654 g/mol and a melting point of 350˚C with decomposition and a vapour pressure of 0.006 mmHg at 200˚C. Log $P_{o/w}$: 9.3. Insoluble in water [EHSI 2004]. Due to the high molecular weight and melting point, significant migration is deemed unlikely. Migration is likely only relevant in contact with fatty products/oils.

Substance	Bis(hexachlorocyclopentadieno) cyclooctane
Potential for exposure of consumers	If used in plastic exposure is judged to be very low. Only in contact with fatty products/oils migration might take place.
Fate of the substance by recycling	Will stay in the plastic by mechanical recycling. By energy recovery the substance will be decomposed. The content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	EHSI (2004). Dechlorane Plus, High Production Volume (HPV) chemical Challenge Program Test plan, prepared by The ENVIRON Health Sciences Institute (EHSI) August 2004 (physical /chemical data). Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.8 Decabromodiphenyl ethane (DBDPE)

Substance	Decabromodiphenyl ethane (DBDPE)
CAS Number	84852-53-9
Justification	List of alternative flame retardants
Function	Flame retardant
Relevant types of plastics	CPE, Engineering thermoplastics, HIPS, PE, PP, thermosets
Main article groups	Electronics, wire cable, construction materials, waterborne emulsions and coatings
Potential for release from plastics	Molecular weight: 971, melting point: 345 °C, boiling point: 676 °C, vapour pressure: 0 at 25° C. Predicted log $P_{o/w}$= 7.8 – 14. Due to the high molecular weight and boiling point, significant migration is deemed unlikely.
Potential for exposure of consumers	Judged to be low to negligible due to the high boiling point.
Fate of the substance by recycling	Will mainly remain in the recycled materials by mechanical recycling.

Substance	Decabromodiphenyl ethane (DBDPE)
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. CAS Chemnet.com, Online database of Chemicals. http://www.chemnet.com/cas/en/84852-53-9/1,2-Bis(pentabromophenyl)-ethane.html UK Environment Agency May (2007), Environmental risk evaluation report: 1,1´-(Ethane-1,2-diyl)bis (penta-bromobenzene). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290840/scho0507bmor-e-e.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromo-diphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.9 Ethylene (bistetrabromophthalimide) (EBTEBPI)

Substance	Ethylene (bistetrabromophthalimide) (EBTEBPI)
CAS Number	32588-76-4
Justification	List of alternative flame retardants
Function	Flame retardant
Relevant types of plastics	HIPS,PP,PP, PBT, OPET, PC and engineering thermoplastics in general
Main article groups	Electrical and electronic components, wire and cable insulation, switches and connectors, construction materials
Potential for release from plastics	Molecular weight: 951.5, melting point: 446 °C. Solubility in water less than 0.1 g/100 ml at 21 °C. Vapour pressure at 25 °C is 2.5 x 10^{-22} mm Hg Due to the high molecular weight and melting point together with the low vapour pressure, migration is deemed unlikely.
Potential for exposure of consumers	Deemed negligible as migration is unlikely.
Fate of the substance by recycling	Will mainly remain in the recycled materials by mechanical recycling.

Substance	Ethylene (bistetrabromophthalimide) (EBTEBPI)
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. ChemBlink.com, online database of chemicals. http://www.chemblink.com/products/32588-76-4.htm Albemarle Corporation (2004). HPV Data summary and test plan for 1H-Isoindole-1,3(2H)-dione, 2,2'-(1,2-ethanediyl)bis(4,5,6,7-tetrabromo-). http://www.epa.gov/hpv/pubs/summaries/1hisoind/c15090.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.10 Tetrabromobisphenol A bis (2,3-dibromopropyl) ether (TBBPA-BDBPE)

Substance	Tetrabromobisphenol A bis (2,3-dibromopropyl) ether (TBBPA-BDBPE)
CAS Number	21850-44-2
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	ABS, HIPS, Phenolic resins, epoxy-laminates (based on similarity to TBBP-A).
Main article groups	Electric and electronic equipment.
Potential for release from plastics	Judged similar to 2,2',6,6'-tetrabromo-4,4'-isopropylidenediphenol (TBBPA - CAS no 79-94-7). TBBPA is a reactive flame retardant (see section 3.5.2). For reactive flame retardants release are limited as they are chemically bound within the polymer.
Potential for exposure of consumers	For reactive flame retardants potential for exposure of consumers is limited as they are chemically bound within the polymer.
Fate of the substance by recycling	Similar to TBBP-A (see section 3.5.2).
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency.

3.5.11 Tris(tribromoneopentyl) phosphate (TTBNPP)

Substance	Tris(tribromoneopentyl) phosphate (TTBNPP)
CAS Number	19186-97-1
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PP.
Main article groups	Electronics, construction materials, cars.

Substance	Tris(tribromoneopentyl) phosphate (TTBNPP)
Potential for release from plastics	Molecular weight: 1018.46 g/mol, melting point: >180°C (decomposition: 309°C), boiling point: 719 °C, vapour pressure: $7x10^{-16}$ mmHg (20°C), water solubility: 0.0156mg/l at 20°C, log P_{ow}: - 4.87 [ResNovae technologies 2011]. Due to the high molecular weight the substance should be assumed not to migrate and be released from plastics.
Potential for exposure of consumers	Low to a negligible potential for exposure of consumers as the substance is assumed not to migrate.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. ResNovae technologies (2011). Material Safety Data Sheet: http://resnovaetech.com/images/safety_sheets/PyroVex++B-115.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.12 Tris(tribromophenoxy) triazine (TTBPTAZ)

Substance	Tris(tribromophenoxy) triazine (TTBPTAZ)
CAS Number	25713-60-4
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	ABS, HIPS.
Main article groups	Electronics.
Potential for release from plastics	The substance is has a molecular weight of 10167g/mol, a melting point of 230°C and a boiling point of 812 °C. Due to the high molecular weight and boiling point the substance should be assumed not to migrate and be released from plastics.
Potential for exposure of consumers	Low to a negligible potential for exposure of consumers as the substance is assumed not to migrate.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.13 Triphenyl phosphate

Substance	Triphenyl phosphate
CAS Number	115-86-6
Justification	List of alternative flame retardants
Function	Flame retardant and plasticiser
Relevant types of plastics	PPE-HIPS, PC-ABS and Cellulose Acetate
Main article groups	Electronics
Potential for release from plastics	The substance is has a molecular weight of 3267 g/mol a melting point of 50.5°C. Boiling point is 245 °C at 11 mmHg. Log P_{ow}: 4.6. Migration is unclear. The high molecular weight indicates no migration. The melting point is, however, low.
Potential for exposure of consumers	Exposure is uncertain. There may be an exposure due to the low melting point.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.14 Bisphenol A bis-(diphenyl phosphate) (BAPP)

Substance	Bisphenol A bis-(diphenyl phosphate) (BAPP)
CAS Number	181028-79-5
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PPE (high impact) and HIPS.
Main article groups	Electronics.
Potential for release from plastics	Molecular weight: 692.65 g/mol, melting point: 90 °C, boiling point: >400 °C, vapour pressure: $<10^{-6}$ mmHg, water solubility: <10-6 g/l, log K_{ow}: 10.0 [Syracuse 2006]. Due to the high molecular weight and boiling point significant migration of the substance is deemed unlikely. The substance is insoluble in water due to the high K_{ow}.
Potential for exposure of consumers	The potential for exposure of consumers is deemed low due to the little migration expected.
Fate of the substance by recycling	Will mainly remain in the plastic by mechanical recycling. By energy recovery the substance will be decomposed.

Substance	Bisphenol A bis-(diphenyl phosphate) (BAPP)
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. Syracuse (2006).Flame retardant Alternatives. Syracuse Research Corporation. http://www.ecy.wa.gov/programs/swfa/pbt/docs/flameretard.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromo-diphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.15 Melamine cyanurate

Substance	Melamine cyanurate
CAS Number	37640-57-6
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PA, PBT, TPU, UP.
Main article groups	Electronics, construction materials, cars, textiles, waterborne emulsions & coatings.
Potential for release from plastics	Molecular weight: 255.2 g/mol, thermally stable up to 440°C, water solubility: 0.01g/l, volatility: 1 % weight loss at 305 °C, 5% loss at 340°C, log K_{ow}: -1.14, -1.34 [BASF 2010a; Metall-Chemie 2014]. The low molecular weight indicates that migration is possible. Other data are, however, scarce. The data available do not allow a solid judgment of, whether migration will take place.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	Unknown.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. BASF (2010a). Melapur MC, Technical information. BASF. http://www.telko.com/files/images/telko/ru/basf/drugie/melapur_mc_tds.pdf Metall-Chemie (2014). Molymet M product description. Metall-Chemie. http://www.mc-chemie.com/fileadmin/user_upload/mc-chemie/pdf/Molymet-M-TDS.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromo-diphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.16 Melamine polyphosphate

Substance	Melamine polyphosphate
CAS Number	15541-60-3
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxy resins, phenolic based composites, PA, PBT, PE, PP, TPU, UP.
Main article groups	Electronics, construction materials, cars, waterborne emulsions & coatings.
Potential for release from plastics	Molecular weight: 430.23 g/mol, melting/boiling points: Starts to decompose ~350°C, water solubility: ~0.08g/100ml at ambient temperature [Hummel Croton 2009]. The low molecular weight indicates that migration is possible. Other data are, however, scarce. The data available do not allow a solid judgment of, whether migration will take place.
Potential for exposure of consumers	Unknown
Fate of the substance by recycling	Unknown. Probably remains in the plastic by mechanical recycling.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. Hummel Croton (2009). Material safety data sheet. Hummel Croton. http://www.hummelcroton.com/msdspdf/mpp_m.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.17 N-alkoxy hindered amine reaction products

Substance	N-alkoxy hindered amine reaction products
CAS Number	191680-81-6
Justification	List of alternative flame retardants.
Function	Flame retardant, UV-stabilizer.
Relevant types of plastics	Polyolefins (PE, PP) [BASF 2010b; US EPA 2014].
Main article groups	Polyolefin fibres, nonwovens and films, construction materials and textiles [BASF 2010b; US EPA 2014].
Potential for release from plastics	Molecular weight: 2261 g/mol, melting point: 108 – 123 °C, boiling point: >400 °C , vapour pressure: < 1.10-4 Pa, water solubility: <40 ppb, volatility: 1 % weight loss at 260 °C, 10 % at 285 °C (recommended for use at temperatures below 250 °C only)[BASF 2010b]. Due to the high molecular weight and boiling point the substance should be assumed not to migrate and be released from plastics
Potential for exposure of consumers	Low to a negligible potential for exposure of consumers.
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.

Substance	N-alkoxy hindered amine reaction products
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. BASF (2010b). Technical Information on Flamestab® NOR 116. BASF. http://www.telko.com/files/images/telko/ru/basf/drugie/flamestab_nor_116_tds.pdf US EPA (2014). An Alternatives Assessment for the Flame Retardant Decabromo-diphenyl Ether (DecaBDE). http://www.epa.gov/oppt/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.18 Phosphonate oligomer, polyphosphonate

Substance	Phosphonate oligomer
CAS Number	68664-06-2
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Thermosets.
Main article groups	Electronics, construction materials.
Potential for release from plastics	Molecular weight: 1,000-5,000 g/mol, softing point: 60 °C, melting point: 180-220 °C, boiling point: >300 °C; vapour pressure: 10^{-8} mmHg (estimated), water solubility: $<10^{-3}$ mg/l [US EPA 2014; FRX 2010]. Due to the high molecular weight and low vapour pressure the substance should be assumed not to migrate and be released from plastics.
Potential for exposure of consumers	Very low.
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	FRX (2010). Material Safety Data Sheet. http://www.frxpolymers.com/frx3100.pdf Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.19 Poly(phosphonate-cocarbonate)

Substance	Poly(phosphonate-co-carbonate)
CAS Number	77226-90-5
Justification	List of alternative flame retardants.

Substance	Poly(phosphonate-co-carbonate)
Function	Flame retardant.
Relevant types of plastics	Engineering plastics (and elastomers).
Main article groups	Electronics, construction materials, cars, aviation applications. Elastomers also for cables.
Potential for release from plastics	Molecular weight: >1,000 g/mol, melting point: 220-250 °C, boiling point: >300 °C (estimated), vapour pressure: $<10^{-8}$ mmHg (estimated), water solubility: $<<10^{-3}$ g/l, log K_{ow}: No data [US EPA 2014]. Due to the high molecular weight, high boiling point and low vapour pressure the substance should be assumed not to migrate and be released from plastics.
Potential for exposure of consumers	Very low.
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.20 Resorcinol bis-diphenylphosphate

Substance	Resorcinol bis-diphenylphosphate
CAS Number	125997-21-9
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PPE-HIPS, PC-ABS.
Main article groups	Electronics.
Potential for release from plastics	Molecular weight: minimum 574.46 g/mol (if only 1 diphenylphosphate group, can contain 1-7), melting point: -16,7 - -12 °C, boiling point: >300 °C (estimated, decomposition may occur before the boiling point is reached), vapour pressure: $1.9x10^{-5}$ mmHg at 20°C (measured), water solubility: 1.05 mg/l at 20°C (measured), log K_{ow}: 4.93 (measured) [US EPA 2014]. Migration may take place (low melting point), but the high boiling point and low vapour pressure as well as low water solubility indicates that migration will be weak.
Potential for exposure of consumers	Low.
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.

Substance	Resorcinol bis-diphenylphosphate
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.21 Aluminium diethylphosphinate

Substance	Aluminium diethylphosphinate
CAS Number	225789-38-8
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxy, polyamide, PBT, PET, TPU.
Main article groups	No information.
Potential for release from plastics	Molecular weight: minimum 390.27 g/mol, melting point: decomposes at 300-330 °C (measured), vapour pressure: 10^{-8} mmHg (estimated), water solubility: 2.5 x 10^{-3} mg/l (measured), log K_{ow}: -0.44 (measured) [US EPA 2014]. Migration may take place, but the high melting point, low vapour pressure and low water solubility indicates that migration will be very low and the substance will most likely not be released from plastics.
Potential for exposure of consumers	Very low.
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.22 Aluminium hydroxide

Substance	Aluminium hydroxide
CAS Number	21645-51-2
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	EVA, PE, thermosets.
Main article groups	No information.

Substance	Aluminium hydroxide
Potential for release from plastics	Molecular weight: minimum 78.01 g/mol, melting point: decomposes at 150-300 °C (measured), vapour pressure: 10^{-8} mmHg (estimated), water solubility: ≤0.09 mg/l (measured) [US EPA (2014)]. The substance is an inorganic compound and therefore solid bound and will not migrate.
Potential for exposure of consumers	No risk.
Fate of the substance by recycling	Depending on the plastic and recycling process in question the substance will either remain in the plastic by mechanical recycling or be decomposed. By energy recycling (normal incineration) the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.23 Ammonium polyphosphate $(NH_4 PO_3)_n$

Substance	Ammonium polyphosphate
CAS Number	68333-79-9
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PE, PP.
Main article groups	No information.
Potential for release from plastics	Molecular weight: ~100,000 g/mol, melting point: decomposes at 150-300 °C, vapour pressure: <10^{-8} mmHg at 25 °C (estimated), water solubility: 0.5% (w/w) at 25°C in 10% suspension (measured) [US EPA, 2014]. Migration ability is unknown, but judged to be very low due to high molecular weight, high melting/deposition point and low vapour pressure.
Potential for exposure of consumers	Unknown – likely very low.
Fate of the substance by recycling	Depending on the plastic and recycling process in question the substance will either remain in the plastic by mechanical recycling or be decomposed. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.24 Magnesium hydroxide

Substance	Magnesium hydroxide
CAS Number	1309-42-8
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	EVA, polyamide, PE, PP.
Main article groups	Electronics (PA). For other plastics: Wire/cables, construction materials, cars, aviation applications. For PE and PP: Storage and distribution products and for PP waterborne emulsions & coatings.
Potential for release from plastics	Molecular weight: ~ 58.32 g/mol, melting point: decomposes at 350-380 °C, vapour pressure: $<10^{-8}$ mm Hg (estimated), water solubility: 1.78 at 20°C, pH 8.3 (measured) [US EPA (2014)]. The substance is an inorganic compound and therefore solid bound and will not migrate.
Potential for exposure of consumers	No risk.
Fate of the substance by recycling	The substance will likely remain in the plastic by mechanical recycling. By energy recycling (normal incineration) the substance will be transformed to magnesium oxide.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.25 Red phosphorus

Substance	Red phosphorus
CAS Number	7723-14-0
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxy resins, PA, PA66, PP.
Main article groups	Electronics. Epoxy also in cars and in aviation applications as well as in waterborne emulsions and coatings. PA also in aviation applications.
Potential for release from plastics	Molecular weight : >1.000 g/mol (estimated), melting point: sublimes at 416-436 °C, vapour pressure: 0.03-0.05 mmHg at 21-25 °C (measured), water solubility: not soluble (measured). Migration ability is unknown, but judged to be very low due to high molecular weight, high sublimation temperature, low vapour pressure and lack of water solubility.
Potential for exposure of consumers	Unknown, but likely very low.

Substance	Red phosphorus
Fate of the substance by recycling	The substance should be assumed to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be transformed to phosphor oxides or similar compounds.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.26 Zinc borate

Substance	Zinc borate
CAS Number	1332-07-06, 138265-88-0
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	PUR, PVC, EVA, PE, PP.
Main article groups	PUR foam, soft PVC products, electronics, wire and cables, construction materials, cars, aviation applications, storage and distribution products. For EVA also waterborne emulsions & coatings.
Potential for release from plastics	Molecular weight minimum: not well defined, melting point: > 650 °C (not well defined), water solubility: 0.28 % at 25 °C [Chemphys, 2008]. Migration ability is unknown, but judged to be low due to high melting point. May, however, migrate to water due to significant water solubility.
Potential for exposure of consumers	Unknown, but likely low.
Fate of the substance by recycling	The substance will remain in the plastic by mechanical recycling. By energy recycling (normal incineration) the substance will be decomposed and transformed to oxides of zinc and boric.
References	Chemphys (2008). Material Safety Data Sheet. http://www.chemphys.com/en/YKTGuanLi/System/UpFile/200881817524346.pdf Gächter R., and Müller H. (1990). Taschenbuch der Kunststoff-Additive, Hansa, ISBN: 3-446-15627-5 Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.27 Tetrabromobisphenol A bis (allyl ether)

Substance	Tetrabromobisphenol A bis (allyl ether)
CAS Number	25327- 89-3
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	EPS.
Main article groups	No information.
Potential for release from plastics	As for other tetrabromobisphenol A based flameretardants (see section 3.5.2 and 3.5.10).
Potential for exposure of consumers	As for other tetrabromobisphenol A based flameretardants (see section 3.5.2 and 3.5.10).
Fate of the substance by recycling	As for other tetrabromobisphenol A based flame retardants (see section 3.5.2 and 3.5.10).
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency.

3.5.28 1,2,5,6- tetrabromocy-clo- octane (TBCO)

Substance	1,2,5,6- tetrabromocy-clo- octane (TBCO)
CAS Number	3194- 57-8
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	EPS (This flame retardant is not functional in current EPS and XPS manufacturing processes. Its thermal stability does not meet operating temperature requirements for the manufacture of XPS foam [US EPA 2013]).
Main article groups	No information.
Potential for release from plastics	Molecular weight: 427.80 g/mol, vapour pressure: 3.59 x 10^{-5} at 25 °C, log K_{ow}: 4.42 [de Wit et al. 2011]. Migration ability is uncertain. The data available are to scarce for solid judgments.
Potential for exposure of consumers	Unknown
Fate of the substance by recycling	The substance is assumed mainly to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	de Wit, CA; Kierkegaard, A; Ricklund, N; Sellstrom, U (2011)."Emerging Brominated Flame Retardants in the Environment" in the book "Brominated flame retardants", Springer. Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. US EPA (2013). Flame retardant alternatives for hexabromocyclodecane (HBCD).

3.5.29 2,4,6- tribromophenyl allyl ether

Substance	2,4,6- tribromophenyl allyl ether
CAS Number	3278-89-5
Justification	List of alternative flame retardants
Function	Flame retardant
Relevant types of plastics	EPS (This flame retardant is recommended in patents as a potential alternative. It is not a potential alternative for the use of HBCD in XPS foam because of its poor thermal stability at operating temperatures. It is not a cost-effective alternative in EPS because it is only viable in the less-economic two-step manufacturing process. This flame retardant may also interfere with the styrene polymerization process, resulting in a product with a lower average MW and more residual unreacted styrene in the product, resulting in foam that will lack the strength to meet building code requirements. [US EPA (2013)]).
Main article groups	No information.
Potential for release from plastics	Molecular weight: 370.86 g/mol, boiling point: 339.5 ±37.0 °C, vapour pressure: 4.9 x 10^{-2} Pa at 25 °C, water solubility: 2.0 x 10^{-2} g/l at 25 °C, log P_{ow}: 4.974±0.564 [Harju et al. 2009]. Migration ability is uncertain. Migration will likely be low due to relatively high boiling point and low vapour pressure.
Potential for exposure of consumers	Unknown, but likely low.
Fate of the substance by recycling	The substance is assumed mainly to remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	US EPA (2013). Flame retardant alternatives for hexabromocyclodecane (HBCD). Harju M, Heimstad ES, Herzke D, Sandanger T, Posner S and Wania F (2009). "Emerging "new" Brominated flame retardants in flame retarded products and the environment" for Norwegian Pollution Control Authority. Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency.

3.5.30 Tetrabromobisphenol A bis(2,3- di-bromopropyl ether) (TBBPA- DBPE), with dicumene for XPS and dicumyl peroxide for EPS, as usual synergists

Substance	Tetrabromobisphenol A bis(2,3- di-bromopropyl ether) (TBBPA- DBPE), with dicumene for XPS and dicumyl peroxide for EPS, as usual synergists
CAS Number	21850-44-2
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	EPS, XPS.
Main article groups	No information.

Substance	Tetrabromobisphenol A bis(2,3- di-bromopropyl ether) (TBBPA- DBPE), with dicumene for XPS and dicumyl peroxide for EPS, as usual synergists
Potential for release from plastics	Molecular weight: 943.61 g/mol, melting point: 90-105 °C, boiling point: 676.5±55.0 °C, vapour pressure: 1.60 x 10^{-7} Pa at 25 °C, water solubility: 1.60 x 10^{-7} g/l at 25 °C, log P_{ow}: 10.422±0.696 [[Harju et al. 2009]]. Potential for release corresponds to other tetrabromobisphenol A based flame retardants (see section 3.5.2 and 3.5.10).
Potential for exposure of consumers	As for other tetrabromobisphenol A based flame retardants (see section 3.5.2 and 3.5.10).
Fate of the substance by recycling	As for other tetrabromobisphenol A based flame retardants (see section 3.5.2 and 3.5.10).
References	Harju M, Heimstad ES, Herzke D, Sandanger T, Posner S and Wania F (2009). "Emerging "new" Brominated flame retardants in flame retarded products and the environment" for Norwegian Pollution Control Authority. Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency.

3.5.31 Ethylenebis (tetrabro-mophthalimide) (EBTPI)

Substance	Ethylenebis (tetrabro-mophthalimide) (EBTPI)
CAS Number	32588-76-4
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	HIPS, polyethylene, polypropylene, thermoplastic polyesters, polyamide, polycarbonate, ethylene co- polymers.
Main article groups	Electronics for HIPS and engineering thermoplastics. For PP and PE also wire/cables, construction materials, cars and storage and distribution products.
Potential for release from plastics	Molecular weight: 951.5 g/mol (measured), boiling point: 886.97 °C (estimated), vapour pressure: 2.54·10^{-22} mmHg at 25°C, partition coefficient (log value) log P_{ow}: 9.80 [Stuer-Lauridsen et al., 2007]. Migration is judged to be very low or negligible due to high molecular weight, high boiling points and low vapour pressure.
Potential for exposure of consumers	Very low.
Fate of the substance by recycling	The substance will remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.

Substance	Ethylenebis (tetrabro-mophthalimide) (EBTPI)
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. Stuer-Lauridsen F., Cohr K.-H. & Andersen T.T. (2007) Health and Environmental Assessment of Alternatives to Deca-BDE in Electrical and Electronic Equipment. Danish Environmental Protection Agency, Environmental Project No. 1142/2007. http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-351-6/pdf/978-87-7052-352-3.pdf

3.5.32 Decabromodiphenyl ethane (DBDPE)

Substance	Decabromodiphenyl ethane (DBDPE)
CAS Number	84852-53-9
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	HIPS, PE, PP, thermosets and CPE.
Main article groups	Electronics, wire and cables, construction materials, cars. For PP and PE also storage and distribution products and for PP waterborne emulsions and coatings.
Potential for release from plastics	Molecular weight: 971.23 g/mol (measured), melting point: 345 °C at 5.00 hPa, vapour pressure: ~1 x 10^{-6} Pa at 25 °C, partition coefficient (log value) log P_{ow}: in the region of 7 – 8 or more [UK Environment Agency 2007]. Migration is judged to be very low or negligible due to high molecular weight, high boiling points and low vapour pressure.
Potential for exposure of consumers	Very low.
Fate of the substance by recycling	The substance will remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. UK Environment Agency (2007). Environmental risk evaluation report: 1,1'-(Ethane-1,2-diyl)bis[penta-bromobenzene]. http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0507bmor-e-e.pdf US EPA (2014). An alternatives Assessment for the flame retardant decabromodiphenyl ether. http://www.epa.gov/dfe/pubs/projects/decaBDE/deca-report-complete.pdf

3.5.33 Diphenyl cresyl phosphate

Substance	Diphenyl cresyl phosphate
CAS Number	26444-49-5
Justification	List of alternative flame retardants.
Function	Flame retardant, plasticiser.
Relevant types of plastics	HIPS (flame retardant), PVC (plasticiser). Mostly used as plasticiser for PVC. Is not used as DecaBDE replacement.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 340.31 g/mol (measured), boiling point: 235 - 255 °C at 5.00 hPa, vapour pressure: < 0,001 hPa at 25 °C, partition coefficient (log value) log K_{ow}: 3.7 at 25 °C [Sigma-Aldrich, 2014a]. Migration unknown, but possible due to low molecular weight and low boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. Sigma-Aldrich (2014a). Material Safety Data Sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=32957&brand=FLUKA&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DCAS%2520No.%26term%3D26444-49-5%26N%3D0%26mode%3Dpartialmax%26focus%3Dproduct%26lang%3Den%26region%3DDK

3.5.34 6H-Dibenz[c,e][1,2]oxaphosphorin, 6-oxide (DOPO)

Substance	6H-Dibenz[c,e][1,2]oxaphosphorin, 6-oxide (DOPO)
CAS Number	35948-25-5
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxies.
Main article groups	Printed circuit boards.
Potential for release from plastics	Molecular weight: 216.18 g/mol (measured), boiling point: 359 °C at 760 mm Hg (extrapolated), vapour pressure: 2.2 x 10^{-5} mm Hg at 25 °C (extrapolated), water solubility: 0.51 g/l (estimated), partition coefficient (log value) log P_{ow}: 1.87 (Estimated) [US EPA, 2008b] Migration possible due to low molecular weight, low boiling point and notable water solubility. Vapour pressure, on the other hand, is low.

Substance	6H-Dibenz[c,e][1,2]oxaphosphorin, 6-oxide (DOPO)
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The material can only be recycled by feed stock recycling or energy recovery. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. U.S. EPA (2008b). FLAME RETARDANTS IN PRINTED CIRCUIT BOARDS - Revised review draft. http://www.epa.gov/dfe/pubs/projects/pcb/full_report_pcb_flame_retardants_report_draft_11_10_08_to_e.pdf

3.5.35 Poly-(m-phenylene methylphosphonate)(Fyrol PMP)

Substance	Poly-(m-phenylene methylphosphonate)
CAS Number	63747-58-0
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxies.
Main article groups	Printed circuit boards.
Potential for release from plastics	Molecular weight: >1.000 (measured) g/mol, boiling point: >400 (estimated) °C, vapour pressure: $<10^{-6}$ mm Hg (estimated), partition coefficient (log value) log P_{ow}: data not available [US EPA, 2008b]. Migration is judged to be very low or negligible due to high molecular weight, high boiling points and low vapour pressure.
Potential for exposure of consumers	Low to negligible.
Fate of the substance by recycling	The material can only be recycled by feed stock recycling or energy recovery. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. U.S. EPA (2008b). FLAME RETARDANTS IN PRINTED CIRCUIT BOARDS - Revised review draft http://www.epa.gov/dfe/pubs/projects/pcb/full_report_pcb_flame_retardants_report_draft_11_10_08_to_e.pdf

3.5.36 Phosphoric acid, diethyl-, aluminium salt

Substance	Phosphoric acid, diethyl-, aluminium salt
CAS Number	225789-38-8

Substance	Phosphoric acid, diethyl-, aluminium salt
Justification	List of alternative flame retardants.
Function	Flame retardant.
Relevant types of plastics	Epoxies.
Main article groups	Printed circuit boards.
Potential for release from plastics	Molecular weight: no data, water solubility: 2.5 g/l, partition coefficient (log value) log P_{ow}: log K_{ow}: -0.44 [Stuer-Lauridsen et al. 2007]. The substance is solid bond as a salt. Will only be released to a minor degree by wear and tear.
Potential for exposure of consumers	No risk.
Fate of the substance by recycling	The material can only be recycled by feed stock recycling or energy recovery. By energy recovery of the plastic by incineration the substance will be decomposed.
References	Lassen C., Jensen A.A., Crookes M., Christensen F., Jeppesen C.N., Clausen A.J., Mikkelsen S.H. (2013). Brominated flame retardants - Part of the LOUS-review. Danish Environmental Protection Agency. Stuer-Lauridsen F., Cohr K.-H. & Andersen T.T. (2007). Health and Environmental Assessment of Alternatives to Deca-BDE in Electrical and Electronic Equipment. Danish Environmental Protection Agency, Environmental Project No. 1142/2007. http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-351-6/pdf/978-87-7052-352-3.pdf

3.5.37 1,3,4-Metheno-1H-cyclobuta[cd]pentalene (MIREX)

Substance	1,3,4-Metheno-1H-cyclobuta[cd]pentalene
CAS Number	2385-85-5
Justification	List of CMR-substances in toy.
Function	Flame retardant (plastics) – also known as pesticide – included on the list of banned substances under the Stockholm Convention.
Relevant types of plastics	No information – highly unlikely that it is actually used.
Main article groups	No information - highly unlikely that it is actually used.
Potential for release from plastics	Molecular weight: 545.59 g/mol, melting point: 483-487 °C, vapour pressure: 3 x 10-7 mm Hg at 25 °C, partition coefficient (log value) log P_{ow}: 5.28 [US EPA, 2003a].
Potential for exposure of consumers	No information - highly unlikely that it is actually used.
Fate of the substance by recycling	No information - highly unlikely that it is actually used.

Substance	1,3,4-Metheno-1H-cyclobuta[cd]pentalene
References	U.S. EPA (2003a). "Toxicological review of Mirex – review draft". ChemCAS (2008). Material Safety Data Sheet for Mirex, CAS 2385-85-5. http://www.chemcas.org/msds114/supplier/cas/729/2385-85.asp Stockholm Convention (2014). The 12 initial POPs under the Stockholm Convention. http://chm.pops.int/TheConvention/ThePOPs/The12InitialPOPs/tabid/296/Default.aspx

3.5.38 Antimony trioxide

Substance	Antimony trioxide
CAS Number	1309-64-4
Justification	Registry of intentions (CLP); List of CMR-substances in toy; List of flame retardants.
Function	Flame retardant, stabiliser.
Relevant types of plastics	Various plastics.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 291.5, melting point: 655-656 °C, boiling point: 1425 °C. Slightly soluble in hot water. Log $P_{o/w}$ unknown. The substance is an inorganic compound and therefore solid bound and will not migrate. Judged to be only liberated by tear and wear.
Potential for exposure of consumers	No risk. Will not migrate.
Fate of the substance by recycling	Remain in the plastic by mechanical recycling. By energy recovery of the plastic by incineration the substance will decompose.
References	Integrated Lab. (2005). Antimony Trioxide, Brief Review of Toxicological Literature, Integrated Laboratory systems, July 2005.

3.5.39 Trixylyl phosphate

Substance	Trixylyl phosphate
CAS Number	25155-23-1
Justification	Registry of intentions (CLP, SVHC); CMR.
Function	Intermediate used for manufacturing and use of plastic products [ECHA 2013]. Aryl phosphates are generally used as flame-retardant additives in polymer systems [UK Environment Agency 2009].
Relevant types of plastics	No information.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 410.45 g/mol, melting point: -20 °C, boiling point: >300 °C at atm.pressure, vapour pressure: 8.7 x 10^{-6} Pa at 20°C, water solubility: 0.89 mg/l (room temperature), log P_{ow}: 5.63 [UK Environment Agency 2009]. Migration is deemed possible due to the low melting point.

Substance	Trixylyl phosphate
Potential for exposure of consumers	Unknown but possible.
Fate of the substance by recycling	If used in thermoplastics judged mainly to remain in the plastic by mechanical recycling. Thermosetting plastics can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	ATSDR (2012c). Toxicological Profile for Phosphate Ester Flame Retardants. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp ECHA (2013). Information on chemicals. http://www.echa.europa.eu/da/information-on-chemicals/registered-substances Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. UK Environment Agency (2009). An overview of the environmental risk evaluation reports for aryl phosphate esters. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290484/scho0809bqtz-e-e.pdf

3.5.40 TDCP (Tris[2-chloro-1-(chloromethyl)ethyl] phosphate)

Substance	TDCP (Tris[2-chloro-1-(chloromethyl)ethyl] phosphate)
CAS Number	13674-87-8
Justification	Registry of intentions (CLP); CMR.
Function	Flame retardant additive for polyurethane at typical loadings of ~ 3% w/w. [RAR-TDCP 2008].
Relevant types of plastics	Polyurethane.
Main article groups	Flexible foams for the automotive industry and furniture [RAR-TDCP 2008].
Potential for release from plastics	Molecular weight: 430.91, melting point: below -20 °C, boiling point: 326 °C (decomposition occurs), vapour pressure: 5.6 x 10^{-6} Pa at 25 °C, water solubility: 18.1 mg/l at 20 °C, log K_{ow}: 3.69 at 20 °C. Might migrate due to the low molecular weight, low melting point and the low log K_{ow}.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	The substance is assumed mainly to remain in the plastic by mechanical recycling. By feed stock recycling or energy recovery of the plastic by incineration the substance will be decomposed. The content of chlorine may by incineration add to formation of dioxins and HCl in the chimney system.
References	EURAR-TDCP 2008. Tris[2-chloro-1-(chloromethyl)ethyl]phosphate (TDCP). Summary. http://echa.europa.eu/documents/10162/e3e784ff-48fa-4fbc-8972-b7fe70cb38bf

3.5.41 Tetrakis(2,6-dimethylphenyl)-m-phenylene biphosphate

Substance	Tetrakis(2,6-dimethylphenyl)-m-phenylene biphosphate
CAS Number	139189-30-3
Justification	Registry of intentions (CLP).
Function	Used as a fire-preventing agent in electronic circuit boards for products such as mobile phones, personal computers, televisions and video recorders. Added in amounts 10-20 % weight.
Relevant types of plastics	Styrene based plastics.
Main article groups	Electrical and electronic products without halogenated flame retardants [Daring & Dietrich's, 2009].
Potential for release from plastics	Molecular weight: 686.67, boiling point: 632 °C at 760 mm Hg [Guidechem 2014a]. Migration possible as not solid bound.
Potential for exposure of consumers	Possible, but unknown.
Fate of the substance by recycling	The substance will remain in the plastic during mechanical recycling. By feed stock recycling and energy recovery the substance will be decomposed.
References	Guidechem (2014a). CAS No. 139189-30-3 (Phosphoric acid,P,P'-1,3-phenylene P,P,P',P'-tetrakis(2,6-dimethylphenyl) ester). http://www.guidechem.com/cas-139/139189-30-3.html Döring M., Diederichs J., (2009). Innovative Flame Retardants in E &E Applications - Non-Halogenated phosphorous, inorganic and nitrogen flame retardants. Pinfa, Cefic, Brussels.

3.6 Monomers, cross linkers, hardeners, chain modifiers and catalysts

This group of substances is very broad and with a high variety of chemical structure. Monomers are the building blocks for the plastic polymers and cover lowboiling gasses (e.g. ethylene, propylene, butadiene, and formaldehyde), reactive solvents (e.g. styrene) and solids (MDA, MOCA). Cross linkers and hardeners and catalysts are all substances used for speeding up chemical reactions in the polymerisation of plastics typically for the thermosetting plastics (epoxy, PUR, UP). Chain modifiers are used to modify the properties of the plastic polymer (e.g. butanediol).

Although these substances generally will react in the process of polymer formation, residues of monomers and reactive compounds may be present in the final products. These residues is a result of that not all monomers/compounds succeeds in reacting during the polymerisation process. Typical concentrations of residues left are 0-2 %. Curing agents inclusive of peroxides and other cross linkers, catalysts, accelerators are typically used in concentrations of 0.1-2%.

Ability to migrate, potential for exposure of consumers and fate by recycling differ between substances and no general rules can be presented.

It should be noted that tin stabilizers (see section 3.8.5 and 3.8.6) will also function as catalysts in the production of PU besides their function as stabilizer in PVC.

3.6.1 Acrylamide

Substance	Acrylamide
CAS Number	79-06-1
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Intermediate – Co-monomer [Kostikov, 1995; ECHA 2009a].
Relevant types of plastics	Polyacrylamide [ECHA 2009a]. Polyacrylonitrile copolymer [Kostikov, 1995].
Main article groups	Acrylamide is almost exclusively (France 2005: 99,54%) used for the synthesis of polyacrylamides, which are used as flocculating agent, in particular in waste water treatment and paper processing. Minor uses include soft contact lenses, cosmetics and comonomer for acrylic fibres [ECHA 2009a; NICNAS 2002; Kostikov, 1995]. Other uses of acrylamide includes the preparation of polyacrylamide gels for research purposes, grouting agent in civil engineering and the production of acrylic/acrylamide resins used in household appliances and in automotive engineering (for covering and coating of automotive parts).
Potential for release from plastics	Molecular weight: 71.09 g/mol, melting/freezing point: 84.5 °C, boiling point: 125°C at 25 mm Hg or 3.3 kPa, vapour pressure: 0.9 Pa at 25°C, water solubility: 2,155 g/l at 30°C, partition coefficient (log value): -1.0 [Annex XV dossier 2009]. Residual monomer is not chemically bound to the polymer and will migrate. Besides residual monomer from production, monomers may be released by weathering processes (hydrolysis). All monomers present may migrate. [Nilsson, 2008].

Substance	Acrylamide
Potential for exposure of consumers	Primary exposure to acrylamide is by ingestion of contaminated food. The acrylamide in food is formed by grilling or baking starch rich food (e.g. French fries). Tobacco smoke is another risk for exposure to acrylamide. In areas near plastic and dye manufacturing plants, drinking water might contain acrylamide. Exposure from the use as soft contact lenses might be very limited, based on expert judgement as the residual amount of monomer is considered very low. Exposure may occur in laboratories using polyacrylamide gels (professionals).
Fate of the substance by recycling	Due to the low boiling point the substance will likely evaporate at least partly by mechanical recycling. Residues of the substances may, however, be present in recycled materials.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_netherlands_cmr_acrylamide_20090831_en.pdf ATSDR 2012a. Toxicological Profile for Acrylamide. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp ECHA (2009a). COMMENTS AND RESPONSE TO COMMENTS ON ANNEX XV SVHC for Acrylamide - CAS number: 79-06-1 http://echa.europa.eu/documents/10162/13638/rcom_final_cc009698-48_acrylamide_nonconf_12112009_en.pdf (Nov. 2012). Kostikov, V.I. (ed.) (1995). Fibre science and technology. Chapman and Hall, London. NICNAS (2002). Acrylamide. Priority Existing Chemical Assessment Report No. 23. National Industrial Chemicals Notification and Assessment Scheme. Australia 2002. Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, Dec. 2012.

3.6.2 4-(1,1,3,3-tetramethylbutyl)phenol, (4-tert-Octylphenol)

Substance	4-(1,1,3,3-tetramethylbutyl)phenol, (4-tert-Octylphenol) - see also section 3.34.
CAS Number	140-66-9
Justification	Candidate list; Norwegian priority list; Registry of intentions (SVHC).
Function	As a monomer for polymer preparations. As an intermediate for manufacture of ethoxylates. As a component in phenolic resins used in the formulation of adhesives. As a component in coatings, incl. insulation of electric windings (e.g. in motors and transformers) to improve insulation and to bond windings together. [Annex XV dossier; DEFRA 2008].
Relevant types of plastics	Phenol resins [UK Environment Agency, 2005].
Main article groups	98% used as an intermediate for the production of phenolic resins (mainly for rubber) and 2% used for octylphenol ethoxylates [Annex XV dossier]. No other information is available

Substance	4-(1,1,3,3-tetramethylbutyl)phenol, (4-tert-Octylphenol) - see also section 3.34.
Potential for release from plastics	Molecular weight: 206.32 g/mol, melting/freezing point: 79 – 82 °C, boiling point: 280 – 283°C, vapour pressure: 0.001 kPa at 20 °C, water solubility: 19 mg/l at 22 °C, log P_{ow}: 3.7. Most of the 4-tert-octylphenol in the resins is chemically bound and cannot be released even on subsequent chemical or biological degradation, but the resins may also contain a small proportion (~3-4%) of unreacted substance that may migrate out of the resin.
Potential for exposure of consumers	Residual 4-tert-Octylphenol in the resins might migrate as the molecular weight is low and the boiling point also fairly low. The log K_{ow} is 5.5 and the solubility in water is 3.1 mg/l at 25 C (estimated). Migration to fat or oils will thus be the most likely pathway for exposure. It is judged that the risk for exposure is very low, if the manufacturing processes have been in control.
Fate of the substance by recycling	If present unreacted substance will likely react or evaporate by mechanical recycling.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_equivalent_concern_4-tert-octylphenol_20110829_en.pdf DEFRA (2008). 4-tert-Octylphenol Risk Reduction Strategy and Analysis of Advantages and Drawbacks. Department for Environment, Food and Rural Affairs. UK. http://archive.defra.gov.uk/environment/quality/chemicals/documents/op-rrs-aad-report.pdf UK Environment Agency (2005). Environmental Risk Evaluation Report: 4-tert-Octylphenol. http://cdn.environment-agency.gov.uk/scho0405biyz-e-e.pdf US EPA (2009c). Screening-level hazard characterization Alkylphenols Category, September 2009.

3.6.3 Bisphenol A (BPA)

Substance	Bisphenol A (BPA)
CAS Number	80-05-7
Justification	Danish list of undesired substances; Norwegian priority list; Registry of intentions (CLP, restriction); List of CMR substances in toy.
Function	Monomer (polycarbonate, epoxy resin, unsaturated polyester resin), used in processing (not further specified, of phenoplast cast resin), antioxidant (in PVC processing and in production of plasticisers for PVC), ingredient in PVC additive package, crosslinking agent (rigid polyurethane foam), unspecified function (modified polyamide) [EU, 2010] Note: The use in PVC manufacture is being phased out [EU, 2010].
Relevant types of plastics	Polycarbonate, epoxy resins, phenoplast cast resin, PVC, rigid polyurethane foam, modified polyamide, unsaturated polyester resin.
Main article groups	All polycarbonate plastics, and many epoxy resins, some phenoplast e.g. phenoplast high pressure laminate compact panels, and PVC articles (groups not specified).

Substance	Bisphenol A (BPA)
Potential for release from plastics	Based on the chemical properties of bisphenol A (molecular weight: 228 g/mol, boiling point: 288˚C, water solubility: 300 mg/l, log K_{ow}: 3.4 [EU, 2010]) it should be regarded as a semi-volatile compound able to migrate out of plastics. Given sufficient time, the major part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	Studies of baby dummies with shield, ie.the hard part, made of polycarbonate, which consists of bisphenol A, available on the Danish marked, have been conducted. Very low migration of bisphenol A was observed.
Fate of the substance by recycling	By mechanical recycling it is judged that free bisphenol A, if present, mainly will remain in the plastic by recycling of polycarbonate and PVC and modified polyamide.
References	ATSDR 2012b. Toxicological Profile for bisphenol A. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp Biles, J.E., McNeal, T.P., Begley, T.H., Hollifield, H.C. (1997). Determination of bisphenol A in reusable polycarbonate food-contact plastics and migration to food-simulating liquids. Journal of Agricultural and Food Chemistry 45:3541–3544. EU (2010). European Union Risk Assessment report 4,4'- Isopropylidenediphenol (Bisphenol-A) CAS No: 80-05-7. EINECS No: 201-245-8. RISK ASSESSMENT. http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/bisphenolareport325.pdf Lassen C., Mikkelsen S.H., Brandt U.K. (2011). Migration of bisphenol A from cash register receipts and baby dummies. Survey of Chemical Substances in Consumer Products 110. Danish Environmental Protection Agency. Wong, K.O., Leo L.W., Seah, H.L. (2005). Dietary exposure assessment of infants to bisphenol A from the use of polycarbonate baby milk bottles. Food Additives and Contaminants 22:280–288.

3.6.4 Formaldehyde

Substance	Formaldehyde
CAS Number	50-00-0
Justification	Danish list of undesired substances; Registry of intentions (CLP); List of CMR-substances in toy.
Function	Monomer.
Relevant types of plastics	Melamine, phenolic resins, acetal resins, POM.
Main article groups	Kitchen equipment, electric and electronic equipment and insulation products. POM is also used in armatures for drinking water.
Potential for release from plastics	Molecular weight: 30 g/mol, melting point: -92 ºC, boiling point: -19.5 ºC, water solubility: 400 g/l (25 ºC), vapour pressure: 3,890 mm Hg (25 ºC), log K_{ow}: 0.35 [NTP 2011]. The physical properties of formaldehyde mean that unreacted formaldehyde should be expected to migrate strongly. The strong evaporation of the substance means that occupational exposure may be given special attention.

Substance	Formaldehyde
Potential for exposure of consumers	There is a potential risk for exposure caused by unreacted monomer or depolymerisation caused by acidic hydrolysis (POM, melamine, phenolic resins) and alkaline hydrolysis (phenolic resins).
Fate of the substance by recycling	By mechanical recycling unreacted formaldehyde may likely evaporate due to the low boiling point and the very high vapour pressure. The substance will most likely not be present in recycled materials. Melamine and phenolic resins can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted formaldehyde will likely evaporate and be decomposed.
References	Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014. NTP 2011. Formaldehyde CAS No. 50-00-0. Report on Carcinogens, Twelfth Edition (2011). National Toxicology Program, Department of Health and Human Services. http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/formaldehyde.pdf

3.6.5 Formaldehyde, oligomeric reaction products with aniline

Substance	Formaldehyde, oligomeric reaction products with aniline
CAS Number	25214-70-4
Justification	Candidate list; Registry of intentions (SVHC).
Function	Intermediate for selected high performance polymers, hardener for epoxy resins. Dominant application is intermediate for methylene diphenyldiisocyanate (MDI). [Annex XV dossier].
Relevant types of plastics	Epoxy resins, high performance polymers (not specified) [Annex XV dossier].
Main article groups	Epoxy: rolls with composite cover, chemically resistant pipes, moulds [Annex XV dossier].
Potential for release from plastics	Molecular weight: > 168 g/mol, melting/freezing point: 30 — 70 °C, boiling point: 410.6 °C at 1013.25 hPa, vapour pressure: < 0.000001 hPa; 20 °C, water solubility: 1.22 g/l, temp. 20 °C; pH 7.5 — 7.6, log K_{ow}: 2.5 at 23 °C [Annex XV dossier]. Hardeners in epoxy will react with other substances and create chemical bindings. No data on reaction residues in other polymers are available. Migration of reaction residues is possible, but likely low due to the physical properties.
Potential for exposure of consumers	Unknown, but deemed possible depending on the amount of reaction residues actually present.
Fate of the substance by recycling	By mechanical recycling (if relevant) unreacted formaldehyde may mainly remain in the plastics due to the high boiling point and low vapour pressure. Epoxy can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted formaldehyde will likely be decomposed.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_techmda_20110829_en.pdf

3.6.6 Phenol

Substance	Phenol
CAS Number	108-95-2
Justification	Danish list of undesired substances; CMR.
Function	Monomer in the production of phenol-aldehyde plastics.
Relevant types of plastics	Bakelite (phenol-formaldehyde).
Main article groups	Mineral wool and plywood glued with phenol-formaldehyde adhesive.
Potential for release from plastics	Molecular weight: 94 g/mol, melting point: 41 °C, boiling point: 182 °C, water solubility: 41%, log P_{ow}: 1.46. The physical properties of phenol mean that unreacted phenol should be expected to migrate strongly.
Potential for exposure of consumers	There is a potential risk for exposure caused by unreacted monomer or depolymerisation caused by acidic hydrolysis and alkaline (phenolic resins). The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	Bakelite can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted phenol will likely be decomposed.
References	Lise M. Moller L.M., Larsen P.B., Fotel F.L., Slothuus T., Boyd H.B., Hjelmar O., Lam H.R. 2013. Survey of phenol. Part the LOUS review. Danish Environmental Protection Agency. ATSDR 2012c. Toxicological Profile for Phenol, Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service. www.atsdr.cde./toxprofiles/index.asp

3.6.7 Hexahydromethylphthalic anhydride and similar compounds

Substance	Hexahydromethylphthalic anhydride , Hexahydro-4-methylphthalic anhydride, Hexahydro-1-methylphthalic anhydride, Hexahydro-3-methylphthalic anhydride
CAS Number	25550-51-0, 19438-60-9, 48122-14-1, 57110-29-9
Justification	Candidate list; Registry of intentions (SVHC).
Function	Intermediates for manufacture of polyester and alkyd resins and plasticisers for thermoplastic polymers. Hardeners for epoxy resins. Chain cross-linkers for thermoplastic polymers. [Annex XV dossier – MHHPA].
Relevant types of plastics	Polyesters, plasticisers manufactured from the substance, epoxies.
Main article groups	No knowledge.
Potential for release from plastics	Molecular weight is 168 g/mol. The substance is a liquid, which might migrate.
Potential for exposure of consumers	It is judged that there is a potential risk for exposure caused by unreacted substance.
Fate of the substance by recycling	It is not possible to predict the fate of the unreacted substance by mechanical recycling due to lack of data. Epoxy can only be recycled by feedstock recycling or by energy recovering. In both cases the unreacted intermediate will likely be decomposed.

Substance	Hexahydromethylphthalic anhydride , Hexahydro-4-methylphthalic anhydride, Hexahydro-1-methylphthalic anhydride, Hexahydro-3-methylphthalic anhydride
References	Annex XV dossier – MHHPA. Hexahydromethylphthalic anhydride, Hexahydro-4-methylphthalic anhydride, Hexahydro-1-methylphthalic anhydride, Hexahydro-3-methylphthalic anhydride. http://echa.europa.eu/documents/10162/96184c0e-245a-49a2-8a69-691e156dbaf7

3.6.8 Hexahydro-2-benzofuran-1,3-dione and similar compounds

Substance	Hexahydro-2-benzofuran-1,3-dione, cis-cyclohexane-1,2-dicarboxylic anhydride, trans-cyclohexane-1,2-dicarboxylic anhydride, Cyclohexane-1,2-dicarboxylic anhydride
CAS Number	85-42-7, 13149-00-3, 14166-21-3
Justification	Candidate list; Registry of intentions (SVHC).
Function	Intermediate/monomer (resins, plasticisers), hardener (epoxy resins). [Annex XV dossier – HHPA].
Relevant types of plastics	Epoxy resins.
Main article groups	Thermoset epoxy croslinked by dicarboxylic acid anhydrides.
Potential for release from plastics	Molecular weight: 154.2 g/mol, melting/freezing point: 31.9 °C, boiling point: 290.6 °C at 1013 hPa, vapour pressure: 77 Pa at 20°C and 93 Pa at 25°C, water solubility: 4.2 g/l at 20°C and pH 2.9, log K_{ow}: 1.59 at 40 °C [Annex XV dossier]. Migration is possible for unreacted substances due to the low molecular weight and low melting and boiling points.
Potential for exposure of consumers	Possible if unreacted residues are present in the epoxy resins after cure.
Fate of the substance by recycling	Epoxies can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	Annex XV dossier – HHPA. Hexahydro-2-benzofuran-1, 3-dione, cis-cyclohexane-1, 2-dicarboxylic anhydride, trans-cyclohexane-1, 2-dicarboxylic anhydride. http://echa.europa.eu/documents/10162/6a9bf645-3e36-4540-b9b8-48da3afb8245 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.9 Hydrazine

Substance	Hydrazine
CAS Number	302-01-2; 7803-57-8
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Cross linker, chain extender in polyurethane. Intermediate in production of blowing agents in thermoplastics, polymerization initiators for acrylic and vinyl, flame retardants for nylon and smoke suppressant additives for polyurethane foam [Annex XV report].
Relevant types of plastics	Polyurethane [Annex XV report].

Substance	Hydrazine
Main article groups	Polyurethane coatings. End-applications for blowing agents include wind turbine blades, isolation panels, flotation devices, boat structures and seat foams, etc. [Annex XV report].
Potential for release from plastics	Molecular weight: 50.0 g/mol, boiling point: 113.5 ˚C, log $P_{o/w:}$ -1.37. Totally miscible with water. Solid bound due to reactive behaviour in PU. Very reactive substance. Therefore most likely no intermediate residues in the end products. Residues will migrate. [Nilsson, 2012].
Potential for exposure of consumers	Unlikely due to the high reactivity of hydrazine and its difunctionality (at least one group is expected to react in the polymerisation and is thus fixed to the polymer network.
Fate of the substance by recycling	Judged not to be present in recycled plastics due to the difunctionality and high reactivity.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_echa_cmr_hydrazine_en.pdf Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014. Environment Canada 2011. Screening Assessment for the Challenge Hydrazine, January 2011.

3.6.10 4,4'- Diaminodiphenylmethane (MDA)

Substance	4,4'- Diaminodiphenylmethane (MDA)
CAS Number	101-77-9
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Hardener for epoxy resins, intermediate in the manufacture of high-performance polymers [Annex XV dossier] e.g. building block for polyether ether ketone (PEEK) [BASF, 2012].
Relevant types of plastics	Epoxy coatings and composites, and the high-performance polymer polyether ether ketone (PEEK) [BASF, 2012].
Main article groups	Mainly used in epoxy coatings and composites and PEEK [BASF, 2012]. The uses are described as "open use in the skilled trade".
Potential for release from plastics	Molecular weight: 198.3 g/mol, melting/freezing point: 89 °C, boiling point: 398-399 °C at 1013 hPa, vapour pressure: 2.87 x 10-8 hPa at 20 °C, water solubility: 1.25 g/l at 20 °C, log K_{ow} (Partition coefficient octanol/water (log value)): 1.59 [Annex XV dossier 2008]. Depends on the application - will e.g. be solid bound in epoxy due to crosslinking (reactive) behaviour. If present as unreacted residues or due to degradation of colorants or polymers migration should be expected to take place. [Nilsson, 2012].
Potential for exposure of consumers	Consumers might be exposed to the substance from not properly hardened epoxies but no data has been identified which support this judgement. The substance might be formed if methylene diphenyl diisocyanate (MDI – see section 3.6.13) is hydrolysed. It is known that MDA has been found in kitchen wares made of nylon. MDI might be used for crosslinking nylon although it is not known by the public. Thus it cannot be excluded that a major source of exposure to the consumer might be MDI based polyurethane products.

Substance	4,4'- Diaminodiphenylmethane (MDA)
Fate of the substance by recycling	Epoxies can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted MDA will likely be decomposed. MDA present in thermoplastic materials as nylon (PA) may likely remain in the recycled materials due to the high boiling point.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_mda_public_20083006_en.pdf BASF (2012). Webpage: http://www.basf.com/group/corporate/en/brand/4_4_DIAMINODIPHENYLMETHANE_MOL Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.11 2,2'-dichloro-4,4'-methylenedianiline (MOCA)

Substance	2,2'-dichloro-4,4'-methylenedianiline (MOCA)
CAS Number	101-14-4
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Curing agent (for polyurethane resins, epoxy resins and epoxy urethane reins, polystyrene and poly(methylmethacrylate) (PMMA), cross-linker (for polyurethane), chain extender (for polyurethane) or prepolymer [Annex XV dossier].
Relevant types of plastics	Mainly polyurethane (PU) [Annex XV dossier].
Main article groups	PU used in construction, for wheels, cars, electric wire coating, safety belts and recently also in biomaterials such as pace makers and implants, polyurethane coatings, castable urethane (curing agent). Polyurethanes with crosslinking agent can be used in the production of machines, buildings, automobiles, airplanes, mining and sport equipment. [Annex XV dossier].
Potential for release from plastics	Molecular weight: 267.2 g/mol, melting point: 110 °C, boiling point: Decomposing prior boiling at 370 °C, vapour pressure: 0.0017 hPa at 60 °C, water solubility: 13.8 mg/l at 20 °C; pH: 7.6, partition coefficient octanol/water (log value) log K_{ow}: 2.5 at 25 °C and pH ca. 7 [Annex XV dossier]. Solid bound due to reactive behaviour. Unreacted MOCA will, however, migrate due to the low molecular weight. Degradation of some azocolorants used in plastics might result in the liberation of MOCA.
Potential for exposure of consumers	Exposure might happen for all types of the thermosetting plastics where the substance is used if the plastics are not properly cured.
Fate of the substance by recycling	Epoxies and ordinary PU can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted MOCA will likely be decomposed. Unreacted MDA present in thermoplastic materials as polystyrene may likely remain in the recycled materials due to the high boiling point if not bound by chemical reaction. To the extent products containing the substance are directed to incineration the content of chlorine may add to formation of dioxins and HCl in the chimney system.

Substance	2,2'-dichloro-4,4'-methylenedianiline (MOCA)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_echa_cmr_moca_20110829_en.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.12 Other alkylphenols and ethoxylates

Substance	4-tert-Butylphenol, 2,6-Di-tert-butylphenol
CAS Number	98-54-4, 128-39-2
Justification	Danish list of undesired substances; Registry of intentions (CLP).
Function	Intermediate, co-polymer, chain terminator.
Relevant types of plastics	Phenolic resins, polycarbonate.
Main article groups	No information.
Potential for release from plastics	Data for 2,6-Di-tert-butylphenol: Molecular weight: 206 g/mole, melting point: 37 °C, boiling point: 253 °C, log P_{ow}: 4.92. Migration of the unreacted substance may take place due to the low melting and boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The fate by recycling of thermoplastics is unclear. Some evaporation as well as renewed chemical reaction of the unreacted substance may be envisaged. Residues of the substances may, however, be present in recycled materials. Phenolic resins can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted substance will likely be decomposed.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.13 Certain isocyanates

Substance	Methylene diphenyl diisocyanate (MDI), Toluene-diisocyanate, TDI
CAS Number	26447-40-5, 5873-54-1, 101-68-8, 26471-62-5, 584-84-9, 91-08-7
Justification	Danish list of undesired substances; List of CMR substances in toy.
Function	Intermediate – manufacturing of PUR.
Relevant types of plastics	PUR.
Main article groups	All products made of PUR except the PUR based on aliphatic diisocyanates (rubber, sealants and lacquers).

Substance	Methylene diphenyl diisocyanate (MDI), Toluene-diisocyanate, TDI
Potential for release from plastics	MDI has a very low vapour pressure at room temperature and will not evaporate and the migration to water containing liquids will result in hydrolysis to the similar diamine. TDI has a higher vapour pressure at room temperature and might migrate if left as residual monomer in the plastic. By hydrolysis TDI might also be hydrolysed to the similar diamine.
Potential for exposure of consumers	Studies from the Danish EPA indicate that exposure might take place from some PUR products, also products intended for babies. The strong evaporation of TDI means that it is relevant to give special attention to occupational exposure.
Fate of the substance by recycling	Polyurethane can only be recycled by incineration or by feedstock recycling. In both cases isocyanates will be decomposed. In Denmark only incineration is practised.
References	Christensen F., Nilsson N.H., Jeppesen C.N., Clausen A.J. (2013).Survey of certain isocyanates (MDI and TDI) - Part of the LOUS-review. Danish Environmental Protection Agency.

3.6.14 Styrene

Substance	Styrene
CAS Number	100-42-5
Justification	Danish list of undesired substances; Registry of intentions (CLP).
Function	Intermediate
Relevant types of plastics	PS, ABS, SAN, EPS ,Glassfiber reinforced products (styrinated polyesters)
Main article groups	All article groups based on the relevant types of plastics
Potential for release from plastics	Molecular weight: 104.1 g/mol, melting point: -30.6 °C, boiling point: 145 °C, water solubility: 310 mg/l at 25°C, log P_{ow}: 2.95 Migration of the unreacted substance may take place due to the low melting and boiling point.
Potential for exposure of consumers	There is a potential risk for exposure caused by unreacted substance. The strong evaporation of the substance means that it is relevant to give special attention to occupational exposure.
Fate of the substance by recycling	Due to the low boiling point the unreacted substance will likely evaporate at least partly by mechanical recycling. Residues of the substances may, however, be present in recycled materials. Glasfiber reinforced products can only be recycled by incineration or by feedstock recycling. In both cases unreacted styrene will be decomposed. In Denmark only incineration is practised.
References	ATSDR 2012d. Toxicological Profile for Styrene. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp US EPA 1994. OPPT Chemical fact sheets styrene, Dec. 1994. http://www.epa.gov/chemfact/styre-sd.pdf

3.6.15 1,1-dichloroethylene, vinylidene chloride

Substance	1,1-dichloroethylene, vinylidene chloride
CAS Number	75-35-4
Justification	List of CMR-substances in toy.
Function	Monomer.
Relevant types of plastics	Saran (thermoplastic copolymers of vinylidene chloride with monomers of vinyl chloride, acrylonitrile, acrylic esters or unsaturated carboxyl groups) – Saran packaging is due to environmental concerns today manufactured from chlorine-free plastics [DOW 2006; Bellis 2014; Johnson 2014; Dictionary.com 2014].
Main article groups	Fibres, packaging, acid-resistant pipes.
Potential for release from plastics	Molecular weight: 96.9 g/mol, melting point: -123° C, boiling point: 31.6° C, vapour pressure: 600 mm Hg (25° C), moderate water solubility: 2.4 g/l (25° C) [Toxnet 2014]. Migration of the monomer is possible due to low molecular weight and low melting and boiling points.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	By mechanical recycling unreacted substance may likely evaporate due to the low boiling point and the very high vapour pressure. To the extent products containing the substance are directed to incineration the content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	Bellis M. (2014). Saran Wrap ®. http://inventors.about.com/library/inventors/blsaranwrap.htm Dictonary.com (2014). Saran. http://dictionary.reference.com/browse/saran DOW (2006). Product Safety Assessment (PSA): SARAN™ PVDC Resins and Films http://www.dow.com/productsafety/finder/saran.htm Johnsson (2014). Saran – frequently asked questions. http://www.saranbrands.com/faq.asp#3 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Toxnet (2014). Vinylidene chloride http://toxnet.nlm.nih.gov

3.6.16 *p*-dichlorobenzene, 1,4-dichlorobenzene

Substance	p-dichlorobenzene, 1,4-dichlorobenzene
CAS Number	106-46-7
Justification	List of CMR-substances in toy.
Function	Monomer.
Relevant types of plastics	PPS (polyphenylene sulphide).
Main article groups	Surface coatings.

Substance	p-dichlorobenzene, 1,4-dichlorobenzene
Potential for release from plastics	Molecular weight: 147 g/mol, melting point: -53° C, boiling point: 174° C, log P_{ow}: 3.44 [Toxnet 2014]. Migration of the monomer is possible due to low molecular weight and low melting and boiling points.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	Due to the low boiling point the substance will likely evaporate at least partly by mechanical recycling. Residues of the substances may, however, be present in recycled materials. To the extent products containing the substance are directed to incineration the content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	Toxnet (2014). Vinylidene chloride http://toxnet.nlm.nih.gov Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.17 Acrylonitril

Substance	Acrylonitril
CAS Number	107-13-1
Justification	List of CMR-substances in toy.
Function	Monomer.
Relevant types of plastics	ABS, SAN, ASA.
Main article groups	All products based on ABS, SAN, ASA including toys, packaging , drinking water contact products and many technical products including electronic and electrical products.
Potential for release from plastics	Molecular weight: 53 g/mol, melting point: -83° C, boiling point: 77° C, vapour pressure: 86 mm Hg (20 °C), log P_{ow}: 0.25. Acrylonitrile might be left as monomer in the final plastic product in low concentrations. As it is very polar, it has a high solubility in water. Migration of acrylonitrile is possible due to low molecular weight and low melting and boiling points.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	Due to the low boiling point and high water solubility the substance will likely evaporate or be removed by washing in recycling process. The substance will most likely not be present in recycled materials.
References	Chemicalbook (2008). Acrylonitrile (107-13-1). http://www.chemicalbook.com/ProductChemicalPropertiesCB8764818_EN.htm Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.18 1,3-butadiene

Substance	1,3-butadiene
CAS Number	106-99-0
Justification	List of CMR-substances in toy.
Function	Monomer.
Relevant types of plastics	HIPS (high impact polystyrene).
Main article groups	All products made from HIPS.
Potential for release from plastics	Molecular weight: 54.092 g/mol, melting point: < -108.9 °C, boiling point: -4.4 and -4.9°C at 101.325 kPa, vapour pressure: 244.7 kPa at 21°C, water solubility: 0.735 g/l at 20°C, log K_{ow}: 1.85 – 2.22 [ECB 2002a]. 1,3-butadiene is a low boiling gas and is judged to evaporate during moulding of the HIPS consumer goods. 1, 3 – butadiene is, furthermore, used for the production of the polybutadiene rubber, which is added to the polystyrene for improving resistance to impact. For this reason the presence of 1, 3- butadiene in the HIPS is considered to be very low if it is present at all.
Potential for exposure of consumers	Exposure to the consumers is not likely to happen as 1,3-butadiene most likely has evaporated during manufacturing of HIPS.
Fate of the substance by recycling	Is not likely to be present in end products and therefore not in materials being recycled.
References	ECB (2002a). European Union Risk Assessment Report – 1,3 butadiene. http://echa.europa.eu/documents/10162/1f512549-5bf8-49a8-ba51-1cf67dc07b72 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.19 Allyl 2,3-epoxypropyl ether, allyl glycidyl ether, prop-2-en-1-yl 2,3-epoxypropyl ether

Substance	Allyl 2,3-epoxypropyl ether, allyl glycidyl ether, prop-2-en-1-yl 2,3-epoxypropyl ether
CAS Number	106-92-3
Justification	List of CMR-substances in toy.
Function	Intermediate for epoxies and some synthetic rubbers.
Relevant types of plastics	Epoxies.
Main article groups	Unknown.
Potential for release from plastics	Molecular weight: 114.1, boiling point: 134 °C, water solubility: 172 g/l. Migration is possible for unreacted substances due to the low molecular weight and boiling point and high solubility in water.
Potential for exposure of consumers	Unknown, but possible if unreacted residues is present in the epoxy resins after cure.
Fate of the substance by recycling	Epoxies can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.

Substance	Allyl 2,3-epoxypropyl ether, allyl glycidyl ether, prop-2-en-1-yl 2,3-epoxypropyl ether
References	Sheftel V.O. (1990). Toxic properties of polymers and additives. Rapra technologies. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.20 Butyl 2,3-epoxypropyl ether , butyl glycidyl ether

Substance	Butyl 2,3-epoxypropyl ether, butyl glycidyl ether
CAS Number	2426-08-6
Justification	List of CMR-substances in toy.
Function	Intermediate as reactive solvent as epoxy resin additive.
Relevant types of plastics	Epoxies.
Main article groups	Coatings, electronics, structural composites, adhesives.
Potential for release from plastics	The molecular weight is 130 g/mol and the boiling point 152- 164 C. The substance is very reactive due to the oxirane ring structure. Migration is possible for unreacted substances due to the low molecular weight and boiling point.
Potential for exposure of consumers	Unknown, but possible if unreacted residues is present in the epoxy resins after cure.
Fate of the substance by recycling	Epoxies can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	ERSTG (2001). High Production Volume Challenge Program For n-butyl Glycidyl Ether Submitted to the US EPA. The Epoxy Resin Systems Task Group, Dec. 2001. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.21 1,3-bis(2,3-epoxypropoxy)benzene, resorcinol diglycidyl ether

Substance	1,3-bis(2,3-epoxypropoxy)benzene, resorcinol diglycidyl ether
CAS Number	101-90-6
Justification	List of CMR-substances in toy.
Function	Intermediate/monomer.
Relevant types of plastics	Epoxies.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 240.3, boiling point: 451.2 C. The substance is reactive diglycidyl ether like the Bisphenol A types. Migration may take place for unreacted substances due to the low molecular weight and fairly low boiling point.
Potential for exposure of consumers	Some risk for exposure by unreacted substance if present in the cured epoxy resin.

Substance	1,3-bis(2,3-epoxypropoxy)benzene, resorcinol diglycidyl ether
Fate of the substance by recycling	Epoxies can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.22 1,2-epoxy-4-epoxyethylcyclohexane, vinylcyclohexane diepoxide

Substance	1,2-epoxy-4-epoxyethylcyclohexane, vinylcyclohexane diepoxide
CAS Number	106-87-6
Justification	List of CMR-substances in toy.
Function	Monomer, reactive dilutant.
Relevant types of plastics	Epoxies.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 140.2 g/mol, melting/freezing point: -108.9 °C, boiling point: 142.2 °C, vapour pressure: 0.1 torr at 20°C, water solubility: water-soluble [Chhabra 1989]. Migration is possible for unreacted substances due to the low molecular weight and low melting and boiling points and water solubility.
Potential for exposure of consumers	Possible if unreacted residues are present in the epoxy resins after cure.
Fate of the substance by recycling	Epoxies can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	Chhabra R. (1989). Toxicology and carcinogenesis studies of 4-vinyl-1-cyclohexene diepoxide (CAS NO. 106-87-6) in F344/N RATS AND B6C3F1 mice (dermal studies). NTP Technical report. http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr362.pdf

3.6.23 1,5-naphthylenediamine

Substance	1,5-naphthylenediamine
CAS Number	2243-62-1
Justification	List of CMR-substances in toy.
Function	Intermediate.
Relevant types of plastics	PUR.
Main article groups	No information.
Potential for release from plastics	The substance has a molecular weight of 158.2 g/mol and a boiling point of 200-210 °C at 5 mm Hg. Water solubility is less than 0.1 g /100 ml. Migration may take place for unreacted substances due to the low molecular weight and fairly low boiling point.
Potential for exposure of consumers	Unknown, but judged possible if present due to the low molecular weight.
Fate of the substance by recycling	Polyurethane can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.

Substance	1,5-naphthylenediamine
References	Chemical Book. CAS DataBase List. http://www.chemicalbook.com/CASEN_2243-62-1.htm Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.24 1,2-epoxybutane

Substance	1,2-epoxybutane
CAS Number	106-88-7
Justification	List of CMR-substances in toy; Registry of intentions (CLP).
Function	Intermediate.
Relevant types of plastics	Epoxies.
Main article groups	No information.
Potential for release from plastics	1,2- epoxybutane has a molecular weight of 72.1 g/mol and is a low boiling liquid (b.p.63°C) and very reactive. The risk for unreacted 1,2- ethoxybuthane in the plastic is considered very low as it is used as an intermediate in initial reactions. Low monomer residual is expected to react with water in humid conditions.
Potential for exposure of consumers	The potential is considered negligible as it is judged that 1,2-epoxybutane will not be present in high enough concentrations to be a risk.
Fate of the substance by recycling	It is judged that 1,2-epoxybutane will not be present in the end of life plastic as it is judged to have reacted with a nucleophile by ring opening of the oxyrane ring.
References	ALS Environmental 2014a. http://www.caslab.com/1-2-epoxybutane_CAS_106-88-7/ Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.25 Methyloxirane (Propylene oxide)

Substance	Methyloxirane (Propylene oxide)
CAS Number	75-56-9
Justification	Candidate list; Registry of intensions (CLP, SVHC); CMR.
Function	Intermediate/monomer (polyether polyol, thermoplastics) [ECHA 2013; Wikipedia – propylene oxide]. Most common use is the manufacturing of polyols for PUR.
Relevant types of plastics	PUR, thermoplastics.
Main article groups	No information.
Potential for release from plastics	Propylene oxide has a molecular weight of 58.1 g/mol and is a low boiling liquid (b.p. 34°C) and very reactive. The risk for unreacted propylene oxide in the plastic is considered very low as it is used as an intermediate in initial reactions. Low monomer residual is expected to react with water in humid conditions.
Potential for exposure of consumers	The potential is considered negligible as it is judged that propylene oxide will not be present in high enough concentrations to be a risk.

Substance	Methyloxirane (Propylene oxide)
Fate of the substance by recycling	Judged not to be present in the end of life plastic as it is judged to have reacted with a nucleophile by ring opening of the oxirane ring.
References	ECHA (2013). Information on chemicals. http://www.echa.europa.eu/da/information-on-chemicals/registered-substances Wikipedia – propylene Oxide (2013). Propylene Oxide. http://en.wikipedia.org/wiki/Propylene_oxide (Nov. 2013) Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.26 1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione (TGIC) & 1,3,5-tris[(2S and 2R)-2,3-epoxypropyl]-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione (β-TGIC)

Substance	1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione (TGIC) [1] 1,3,5-tris[(2S and 2R)-2,3-epoxypropyl]-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione (β-TGIC) [2] [1] Contains a combination of isomers 90% α and 10% β isomer. [2] Exist and is used only as a part of TGIC (mixture of isomers, 90% α and 10% β isomer) [Annex XV dossier]
CAS Number	2451-62-9; 59653-74-6
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Main function is as a three-dimensional cross-linking or curing agent (in polyester powder coatings). Also used as stabiliser in plastics [Annex XV dossier].
Relevant types of plastics	Polyester. TGIC is an epoxy compound [Annex XV dossier].
Main article groups	The main use is in polyester powder coatings for metal finishing for coated articles (in particular articles for exterior use) such as steel garden furniture, car parts, metal fencing, window and door frames, electrical equipment, refrigerators, washing machines and ovens [Annex XV dossier].
Potential for release from plastics	CAS no. 2451-62-9: Molecular weight: 297.3 g/mol, boiling point: > 240°C (not determined, as decomposition started at 240 °C), vapour pressure: 0.0072 Pa at 20°C, partition coefficient (log value) log P_{ow}: -0.8, at 20°C (measured). Solid bound due to crosslinking (reactive) behaviour. Release only by wear and tear.
Potential for exposure of consumers	Low risk if totally cross-linked.
Fate of the substance by recycling	The substance will remain in the plastic by mechanical recycling, but partly be decomposed.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13638/svhc_axvrep_tgic_combinationisomers_en.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.6.27 Imidazole

Substance	Imidazole
CAS Number	288-32-4
Justification	Registry of intentions (CLP).
Function	Intermediate - monomers for manufacture of thermoplastics - amine component in PU, Epoxy, etc. [ECHA 2013].
Relevant types of plastics	PU and epoxy.
Main article groups	Unknown.
Potential for release from plastics	Molecular weight: 68.08, melting point: 88-91 °C, boiling point: 256° C [Sigma-Aldrich, 2014i]. Water-soluble strong base. If left in the plastic high risk for migration due to the low molecular weight, low boiling point and high water solubility.
Potential for exposure of consumers	Possible, but unknown.
Fate of the substance by recycling	The substance is judged to be partly removed in the washing step during mechanical recycling. By feedstock recycling or energy recovery the substance will be decomposed.
References	ECHA (2013). Information on chemicals. http://www.echa.europa.eu/da/information-on-chemicals/registered-substances Sigma-Aldrich (2014i). Imidazole www.sigmaaldrich.com/catalog/product/fluka/1336500?lang=en&region=DK

3.6.28 1,4-Diaminobutane (Putrescine)

Substance	1,4-Diaminobutane (Putrescine)
CAS Number	110-60-1
Justification	Registry of intentions (CLP).
Function	Intermediate – production of polyamide (Nylon-4.6), by reaction with adipic acid.
Relevant types of plastics	Nylon-4,6.
Main article groups	Technical PA based products.
Potential for release from plastics	Molecular weight: 88.15, melting point: 27 °C, boiling point: 158-160°C [ALS Environmental 2014b]. If left unreacted the substance might migrate due to the low molecular weight and boiling point. Judged to be very soluble in water.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	If left as monomer in the plastic the substance might remain in the plastic by mechanical recycling, but the risk is considered low because of the solubility in water which means that the substance will be removed in the washing process. By feed stock recycling and energy recovery the substance will be decomposed.
References	ALS Environmental 2014b. 1,4-diaminobutane - CAS 110-60-1. http://www.caslab.com/1-4-diaminobutane_CAS_110-60-1/

3.6.29 Vinyl acetate

Substance	Vinyl acetate
CAS Number	108-05-4
Justification	Registry of intentions (CLP).
Function	Monomer used for PVA, EVA etc.
Relevant types of plastics	PVA, VA/AA, PVCA.
Main article groups	Unknown.
Potential for release from plastics	Molecular weight: 86.09, melting point: -100 °C, boiling point: 72° C, vapour pressure: 100 mm Hg at 22 °C, water solubility: slightly [ALS Environmental 2014c]. Possible if left unreacted due to the low molecular weight and low boiling point.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	Judged to evaporate or to be oxidised by mechanical recycling. Decomposed by feed stock recovery or energy recovery.
References	ALS Environmental 2014c. Vinyl acetate - CAS 108-05-4. http://www.caslab.com/Vinyl_acetate_CAS_108-05-4/

3.7 Organic based colorants

Dyes (soluble) and pigments (insoluble) are widely used in the production of plastics. Whereas pigments may be inorganic or organic, dyes are always organic compounds. Both organic pigments and dyes are available in a variety of colours and must be:

- Stable to weather change;
- Heat stable during processing;
- Freely dispersible in plastics;
- Compatible with the material [Subramanian 2013].

Typical amount of organic based dyes in plastic products is 0.25-5 % (w/w) and for organic based pigments: 0.001-2.5 % (w/w) [Hansen et al, 2013].

All organics colorants addressed in this section is characterised by limited data leading to the judgment that migration and thus also exposure to consumers is uncertain and unknown. It is, however, deemed likely that the colorants by mechanical recycling will remain in the plastic materials.

An organic colorant not presented here is Carbon Black which is produced by incomplete combustion of oil and tar products. Carbon Black is relevant to consider due to the potential content of polyaromatic hydrocarbons (PAHs - see section 3.11.5).

3.7.1 Malachite green hydrochloride, malachite green oxalate

Substance	Malachite green hydrochloride, malachite green oxalate
CAS Number	569-64-2, 18015-76-4
Justification	List of CMR-substances in toy.
Function	Colorant.
Relevant types of plastics	Green coloured plastics.
Main article groups	No information.
Potential for release from plastics	Malachite green hydrochloride: Molecular weight: 364.91 g/mol, boiling point: data not available, vapour pressure: 111 Pa at 50°C, Log P_{ow}: 0.062. Very soluble in organic solvents. [ECHA 2010; Sigma-Aldrich 2014b]. Malachite green oxalate: Molecular weight: 926 g/mol g/mol, melting point: 164 °C, boiling point: 172-175 °C, decomposition: 210 °C, vapour pressure: 111 Pa (50 °C) [ECHA 2010]. Migration is uncertain, but may take place due to the low boiling point.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	The fate by recycling of thermoplastics is unclear. Some evaporation as well as decomposition may take place depending on the plastic type in question. Part of the substance may, however, also be present in recycled materials. Thermosetting plastics can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted substance will likely be decomposed. To the extent products containing the substance are directed to incineration the content of chlorine may add to formation of dioxins and HCl in the chimney system.

Substance	Malachite green hydrochloride, malachite green oxalate
References	ECHA (2010). Background document to the Opinion proposing harmonised classification and labelling at Community level of leucomalachite green ECHA/RAC/CLH-O-0000001309-75-03/A1. http://echa.europa.eu/documents/10162/13641/leucomalachite_green_annex_1_en.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma-Aldrich (2014b). Malachite Green chloride - Material Safety Data Sheet http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=38800&brand=FLUKA&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DCAS%2520No.%26term%3D569-64-2%26lang%3Den%26region%3DDK%26focus%3Dproduct%26N%3D220003048%2B219853103%2B219853286%26mode%3Dpartialmax

3.7.2 *N*-[4-[(2-hydroxy-5-methylphenyl)azo]phenyl]acetamide, C.I. Disperse Yellow 3

Substance	N-[4-[(2-hydroxy-5-methylphenyl)azo]phenyl]acetamide, C.I. Disperse Yellow 3
CAS Number	2832-40-8
Justification	List of CMR-substances in toy.
Function	Colorant.
Relevant types of plastics	Yellow coloured plastics.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 269.3 g/mol, melting point: 268 - 270 °C, vapour pressure: data not available, log P_{ow}: 3.6 [Sigma-Aldrich 2014c]. Migration is uncertain, but may take place due to the low molecular weight. Melting point is, however, relative high.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the high melting point.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma-Aldrich (2014c). Disperse Yellow 3- Material Safety Data Sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=215686&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Faldrich%2F215686%3Flang%3Den

3.7.3 1-phenylazo-2-naphthol, C.I. Solvent Yellow 14

Substance	1-phenylazo-2-naphthol, C.I. Solvent Yellow 14
CAS Number	842-07-9
Justification	List of CMR-substances in toy.
Function	Colorant.
Relevant types of plastics	Yellow coloured plastics.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 248.3g/mol, melting point: 144.4 °C, vapour pressure: 1.27×10^{-5} Pa, log P_{ow}: 5.51 [Environment Canada 2013]. Migration is uncertain, but may take place due to the low molecular weight. Melting point is, however, relative high and the vapour pressure low.
Potential for exposure of consumers	Unknown.
Fate of the substance by recycling	The fate by recycling of thermoplastics is unclear due to lack of data. Some evaporation may take place, but the main part of the substance may well remain in the plastic by mechanical recycling due to the high melting temperature. Thermosetting plastics can only be recycled by feedstock recycling or by energy recovering. In both cases unreacted substance will likely be decomposed.
References	Environment Canada (2013). Aromatic Azo and Benzidine-based Substance Grouping. Certain Azo Solvent Dyes. Appendix of Draft Screening Assessment http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=0C7D0BE6-1842- Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.8 UV stabilisers, antioxidants and other stabilisers

In general stabilizers are added to prevent the plastics from degradation (e.g. by temperature, light, UV light, oxygen and other types of weathering) and thereby prolonging the lifetime of the products.

Heat stabilizers protect polymers during thermal processing to avoid product decomposition during the production process and to protect against heat in long-term use at high temperatures.

UV stabilizers are used to prevent or protect degradation of plastics from ultraviolet rays to extend the life of the end products, whereas antioxidants are used to inhibit the oxidative degradation of plastics [Subramanian 2013].

The amount of heat stabilizers is typically 0.5-3 % (w/w). Typical amount of antioxidants and UV stabilizers in plastic products is 0.05-3 % (w/w) [Hansen et al 2013].

The behaviour differs between the substances. Most substances can be assumed to migrate, but the rate will be so low that the main part will remain in product until it is discarded as waste if migration was the only mechanism for reducing the amount in the plastic.

However antioxidants and many UV stabilisers will be chemically changed during either the production of the plastic products or/and by use of the products. The reason for this is that the stabilisers act in such a way that they will be decomposed instead of the plastic polymers.
This means that by mechanical recycling of plastics it is necessary to add further stabilisers to the plastic for protection against plastic degradation in the new recycled plastic products.

It should be noted the following substances will also function as stabilisers or antioxidants in plastics:

- 1,6-hexanediol diglycidyl ether (section 3.10.5)
- Nonylphenol and its etoxylates (section 3.11.1)
- Octylphenol and its ethoxylates (section 3.11.2)
- 1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione (TGIC) 1) 1,3,5-tris[(2S and 2R)-2,3-epoxypropyl]-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione (β-TGIC) 2) (section 3.6.26)
- Lead and lead compounds (3.4.5)
- Cadmium and cadmium compounds (3.4.1)
- Antimony trioxide (section 3.5.38)

3.8.1 1,4-benzenediol, 2,5-bis(1,1-dimethylethyl)-

Substance	1,4-benzenediol, 2,5-bis(1,1-dimethylethyl)-
CAS Number	88-58-4
Justification	Danish list of undesired substances.
Function	Antioxidant in plastics.
Relevant types of plastics	No information.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 222.33 g/mol, boiling point: 321-324.52°C, vapour pressure: 0.0000009 hPa at 25 °C, partition coefficient (log value) log P_{ow}: 4.85. Not solid bound and will migrate due to low molecular weight and medium high boiling point.
Potential for exposure of consumers	Exposure is deemed possible. But because the substance typically is added in low concentration in the plastic products (0.1-1%) the risk is considered low.

Substance	1,4-benzenediol, 2,5-bis(1,1-dimethylethyl)-
Fate of the substance by recycling	The substance will partly be decomposed by mechanical recycling. Residues may be present in recycled materials, but no practical experience is available.
References	Hansen E., Christensen F.M., Kjølholt J., Jeppesen C.N., Lassen C. (2012b). Survey of 1,4-benzenediol, 2,5-bis(1,1-dimethyl ethyl)- (2,5-di-tert-butylhydroquinone). Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.8.2 Phenolic benzotriazols

Substance	Phenolic benzotriazols (2-benzotriazol-2-yl-4,6-di-tert-butylphenol (UV-320), 2,4-di-tert-butyl-6-(5-chlorobenzotriazol-2-yl)phenol (UV-327), 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol (UV-328), 2-(2H-benzotriazol-2-yl)-4-(tert-butyl)-6-(sec-butyl)phenol (UV-350)
CAS Number	3846-71-7, 3864-99-1, 25973-55-1, 36437-37-3
Justification	Registry of intentions (SVHC).
Function	UV-stabilizer.
Relevant types of plastics	UV320: Polyurethane and other plastics. UV327: Polyurethane and other plastics. UV328: ABS, Epoxy, unsaturated polyester, polypropylene, PVC, polycarbonate, polyacrylate and polyurethane. UV350: Polyurethane and other plastics.
Main article groups	E.g. coated textiles and coating of surfaces on cars and wood etc. – relevant for all surfaces seriously exposed to sunlight.
Potential for release from plastics	CAS no.: 3846-71-7: Molecular weight: 323.4 g/mol, boiling point: 444.0 ± 55.0°C, vapour pressure: $1.70*10^{-8}$ torr at 25 °C, log P_{ow}: 6.853 ± 1.254 at 25 °C (calculated properties). The other substances have similar values. Not solid bound and will migrate due to low molecular weight and medium high boiling point.
Potential for exposure of consumers	Exposure is deemed possible. But because the substance typically is added in low concentration in the plastic products (0.1-1%) the risk is considered low.
Fate of the substance by recycling	The substance will partly be decomposed by mechanical recycling. Residues may be present in recycled materials. Substances used in thermosetting materials as polyurethane and epoxies will be decomposed by feedstock recycling as well as energy recovery.

Substance	Phenolic benzotriazols (2-benzotriazol-2-yl-4,6-di-tert-butylphenol (UV-320), 2,4-di-tert-butyl-6-(5-chlorobenzotriazol-2-yl)phenol (UV-327), 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol (UV-328), 2-(2H-benzotriazol-2-yl)-4-(tert-butyl)-6-(sec-butyl)phenol (UV-350)
References	Annex XV dossier – UV320. http://echa.europa.eu/documents/10162/13638/annex_xv_svhc_ec_223-346-6_uv320_en.pdf Annex XV dossier – UV327. http://echa.europa.eu/documents/10162/06a69fa4-be0d-441e-9a65-471d1ddaa9e3 Annex XV dossier – UV328. http://echa.europa.eu/documents/10162/13641/rac_opinion_annex_UV-328_en.pdf Annex XV dossier – UV350. http://echa.europa.eu/documents/10162/a4fd8518-5e1c-40b7-a8c0-320b9f71f676 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.8.3 *N*-2-naphthylaniline, *N*-phenyl-2-naphthylamine

Substance	N-2-naphthylaniline, N-phenyl-2-naphthylamine
CAS Number	135-88-6
Justification	List of CMR-substances in toy.
Function	Thermo stabilizer, antioxidant.
Relevant types of plastics	PE, EVA, PIB.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 219.28 g/mol, boiling point: 395 – 395.5 °C, vapour pressure: no data available, partition coefficient (log value) log P_{ow}: 5 [Sigma-Aldrich 2014h]. Not solid bound and will migrate due to low molecular weight and medium high boiling point.
Potential for exposure of consumers	Exposure is deemed possible. But because the substance typically is added in low concentration in the plastic products (0.1-1%) the risk is considered low.
Fate of the substance by recycling	The substance will partly be decomposed by mechanical recycling. Residues may be present in recycled materials.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma –Aldrich (2014h). N-Phenyl-2-naphthylamine - Material Safety Data Sheet http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=178055&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DCAS%2520No.%26term%3D135-88-6%26lang%3Den%26region%3DDK%26focus%3Dproduct%26N%3D0%2B220003048%2B219853103%2B219853286%26mode%3Dmatch%2520partialmax

3.8.4 2-ethylhexanoic acid

Substance	2-ethylhexanoic acid
CAS Number	149-57-5
Justification	List of CMR-substances in toy.
Function	Stabilizer (thermo) as a salt.
Relevant types of plastics	PVC and as residue in PUR products.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 144.21 g/mol, boiling point: 227.6 °C, vapour pressure: 1.33 x 10^{-3} kPa at 20°C, log P_{ow}: 3 at 25°C [US EPA 2001]. Not solid bound and will migrate due to low molecular weight and medium high boiling point.
Potential for exposure of consumers	Exposure is possible. But due to typically low concentrations present in products (500 ppm) [Tønning et al 2008] the risk is considered as low.
Fate of the substance by recycling	The substance will partly be decomposed by mechanical recycling. Residues may be present in recycled materials. Substances used in thermosetting materials as polyurethane will be decomposed by feedstock recycling as well as energy recovery.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Tønning K., Pedersen E., Lomholt A.D., Malmgren-Hansen B., Woin P., Møller L., Bernth N. (2008). Kortlægning og afgivelse samt sundhedsmæssig vurdering af kemiske stoffer i babyprodukter. Kortlægning af kemiske stoffer i forbrugerprodukter, Nr. 90/2008. Danish Environmental Protection Agency. US EPA (2001). Robust Summaries and SIDS dossier for 2-Ethylhexanoic Acid. http://www.epa.gov/hpv/pubs/summaries/metalcarb/c14172rr12.pdf

3.8.5 Dibutyltin dichloride

Substance	Dibutyltin dichloride
CAS Number	683-18-1
Justification	Candidate list, Registry of intentions (SVHC); CMR.
Function	Stabiliser in PVC. Catalyser in the production of polyurethanes.
Relevant types of plastics	PVC, polyurethane (PUR).
Main article groups	PVC: food wraps and food packaging, T-shirts, polyurethane gloves, sanitary napkins, medical equipment, cellophane wrap and soft toys, water pipes, packing materials, textile products. Polyurethanes: Foam plastics, glue/sealants, insulators in electronics and cables, transparent plastic.
Potential for release from plastics	Molecular weight: 304 g/mol, melting point: 43 °C, boiling point: 135 °C (10 mm Hg), solubility water: 80 mg/l at 25 °C. Migration is possible due to low molecular weight and low melting and boiling points.

Substance	Dibutyltin dichloride
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	By recycling of thermoplastics some evaporation as well as oxidation must be expected. Residues of the substances may, however, be present in recycled materials. Polyurethane can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised. The content of chlorine may add to formation of dioxins and HCl in the chimney system.
References	Annex XV dossier. Dibutyltin dichloride. http://echa.europa.eu/documents/10162/8a520ac1-f460-447f-9ac4-388768fe0784 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sheftel V.O. (1990). Toxic properties of polymers and additives. Rapra technologies

3.8.6 Other tin stabilizers

Substance	Dimethyltin bis(2-ethylhexylmercaptoacetate) (DMT EHMA); Dioctyltin bis(2-ethylhexyl mercaptoacetate); Dibutyltin dilaurate; Dimethyltin dichloride (DMTC)
CAS Number	57583-35-4, 15571-58-1, 77-58-7, 753-73-1
Justification	Registry of intensions (CLP).
Function	Heat stabilizer in PVC - the substances are added to PVC in amounts of 0.3 – 12 phr (parts per hundred parts PVC). Catalyst in production of PU (dibutyltin laurate) [KEMI – Dibutyltenndilaurate 2013].
Relevant types of plastics	PVC
Main article groups	Plastic doors, windows, pipes for water transport, decorative PVC items etc.
Potential for release from plastics	The substances are liquids or solids with melting points in the range of 22° C to 106 °C and molecular weight in the range 219.69 to 752. Boiling point is from 188 °C and higher. The substances are all strong reducing agents which prevent oxidation of the PVC by being oxidised themselves. The substances are not solid bound and might migrate.
Potential for exposure of consumers	Possible as not solid bound.
Fate of the substance by recycling	It is judged that the substances will remain in the plastic during mechanical recycling but oxidation might take place during the recycling due to the strong reducing properties of the substances. By feed stock recycling and energy recovery the substances are decomposed. To the extent products containing the substance are directed to incineration content of chlorine may add to formation of dioxins and HCl in the chimney system.

Substance	Dimethyltin bis(2-ethylhexylmercaptoacetate) (DMT EHMA); Dioctyltin bis(2-ethylhexyl mercaptoacetate); Dibutyltin dilaurate; Dimethyltin dichloride (DMTC)
References	Chemicalbook (2010a). Dimethyl dichloride (753-73-1). http://www.chemicalbook.com/ChemicalProductProperty_EN_CB1729317.htm Chemicalbook (2010b). Dibutyltin dilaurate (77-58-7). http://www.chemicalbook.com/ChemicalProductProperty_EN_CB7416378.htm Chemnet (2014). 57583-35-4 Methyl Tin Mercaptide. http://www.chemnet.com/cas/en/57583-35-4/Methyl-Tin-Mercaptide.html Health Canada 2013. Priority Substances List Assessment Report for Non-pesticidal organotin compounds. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl1-lsp1/non_pest_org_comp/index-eng.php KEMI (2012). Dibutyltin compounds. http://apps.kemi.se/flodessok/floden/kemamne_eng/dibutyltennforeningar_eng.htm (Nov.2012) KEMI – Dibutyltenndilaurate 2013. http://apps.kemi.se/flodessok/floden/kemamne_eng/dibutyltennd_eng.htm Sigma-Aldrich (2014j). Dibutyltindilaurat CAS no. 77-58-7 – Material safety data sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=291234&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DAll%26term%3D77-58-7%26N%3D0%26mode%3Dpartialmax%26focus%3Dproduct%26lang%3Den%26region%3DDK Vetamo 2014. Methyl Tin Mercaptide. http://www.vetamo.com/181.htm

3.8.7 TNPP (tris(nonylphenyl)phosphite)

Substance	TNPP (tris(nonylphenyl)phosphite)
CAS Number	26523-78-4
Justification	Registry of intentions (CLP).
Function	Stabiliser in the processing of plastic products. They are used with hindered phenolic antioxidants in plastic food packaging. In the stabilisation process, TNPP is gradually oxidised and nonylphenol is released. TNPP is also used as a secondary antioxidant in polymer formulations.
Relevant types of plastics	PVC, LLDPE, HDPE [EURAR – TNPP 2007].
Main article groups	PVC products include shower curtains, floorings and wall coverings. LLDPE films include films for bags and food packaging. HDPE containing TNPP include blow-moulded plastic drums or outer wrapping (film) of cigarette boxes or tea boxes. Other products include tires and shoe soles. [EURAR – TNPP 2007].

Substance	TNPP (tris(nonylphenyl)phosphite)
Potential for release from plastics	Molecular weight: 689, boiling point: 180 °C at 4 hPa, decompose: > 303° C, vapour pressure 0.00008 hPa at 20 °C, log P_{ow}: 19.918 - 21.6, solubility in water: ~0 mg/l. Migration ability is uncertain. Migration will likely be low due to the high boiling point/decomposition temperature and the low vapour pressure. Will not migrate to water. Nonylphenol might migrate, as it is an impurity in the substance.
Potential for exposure of consumers	Possible, but likely to be low.
Fate of the substance by recycling	The substance is assumed mainly to remain in the plastic by mechanical recycling. By feed stock recycling or energy recovery of the plastic by incineration the substance will be decomposed.
References	EURAR – TNPP (2007). Risk Assessment Report – Tris(nonylphenyl)phosphite – draft. http://echa.europa.eu/documents/10162/522e8584-1797-4a11-960b-3c813b37495f ECHA (2009c). Tris(nonylphenol)phosphite CAS No: 26523-78-4 Annex XV Transitional Report. http://echa.europa.eu/documents/10162/13630/trd_cover_page_tris_nonylphenol_phosphite_en.pdf Guidechem (2014b). Phenol, nonyl-,1,1',1''-phosphite (cas 26523-78-4) MSDS http://www.guidechem.com/msds/26523-78-4.html

3.9 Plasticisers

Plasticisers are added to plastic compositions to aid flow and processing (internal lubricants) or softening of plastic by lowering the glass transition temperature (t_g). Plasticisers are of either low melting solids or high boiling liquids and provide:

- Viscosity properties which allow rapid coating and low plasticiser concentration in the plastisol;
- Favourable fusion properties, avoiding long oven times and achieving high production rates;
- Excellent stain-, extraction- and abrasion resistance [Subramanian 2013].

The typical amount of plasticisers in plasticised plastic products is 10-70 % (w/w) [Hansen et al 2013].

The group of plasticisers listed below include phthalates, chlorinated paraffins and recognised alternatives to these substances. Migration of plasticisers to food has been studied for many years with focus on the phthalates of high concern. Generally all the substances listed must be anticipated to migrate and the use in plastics should thus be considered a source of exposure to consumers.

The dominant application is plasticised PVC, but some substances are used for other plasticised plastics inclusive of polyurethane foam, acrylics, polyester etc.

To the best of knowledge the migration rate will typically be at a level low enough to assume that the main part of the plasticisers added to products will remain in the plastics at the end of its in-service life. To the extent these materials are mechanically recycled the plasticisers will also be present in recycled materials, while plasticisers used in thermosetting materials as polyurethane will be decomposed by feedstock recycling as well as energy recovery.

It should be noted that tris(2-chloroethyl)phosphate (TCEP) (see section 3.5.5) and diphenyl cresyl phosphate (see section 3.5.33) will also function as plasticiser besides their function as flame retardant.

3.9.1 1,2-Benzenedicarboxylic acid, di-C7-11-branched and linear alkyl esters

Substance	1,2-Benzenedicarboxylic acid, di-C7-11-branched and linear alkyl esters (DHNUP)
CAS Number	68515-42-4
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Plasticiser (mainly) [Annex XV dossier].
Relevant types of plastics	PVC (mainly), foamed urethane.
Main article groups	Electrical and communication wire insulation (mainly) [Annex XV dossier] dossier.
Potential for release from plastics	DHNUP should be regarded as semivolatile (molecular weight: 362-474 g/mol, boiling point: 235-278 °C at 7 hPa, vapour pressure: <10 Pa at 20 °C). Release rates by migration are probably in the range of 0.1-1% per year or below (analogy considerations to DEHP – see section 3.9.7). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing (Partition coefficient (log value) P_{ow}: ca. 4.8). Tear and wear will also take place but be of minor importance.

Substance	1,2-Benzenedicarboxylic acid, di-C7-11-branched and linear alkyl esters (DHNUP)
Potential for exposure of consumers	Same considerations as for diisoheptylphthalate (see section 3.9.2) based on the close similarity of the substances (molecular weight, aromatic structure, ester functionality.
Fate of the substance by recycling	Same fate as for diisoheptylphthalate (see section 3.9.2)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_dk_cmr_dhnup_en.pdf

3.9.2 1,2-Benzenedicarboxylic acid, di-C6-8-branched alkyl esters, C7-rich (Diisoheptylphthalate)

Substance	1,2-Benzenedicarboxylic acid, di-C6-8-branched alkyl esters, C7-rich (Diisoheptylphthalat)
CAS Number	71888-89-6
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Plasticiser [Annex XV dossier].
Relevant types of plastics	PVC, one-component polyurethanes and acrylics [Annex XV report].
Main article groups	Plasticiser in PVC: vinyl flooring, tile and carpet backing; moulding and coating plastisols (e.g. coating of textiles or other materials); partial replacement for other low molecular weight plasticisers (e.g. DEHP – see section 3.9.7) in extrusion, injection moulding and calendaring applications requiring improved process ability.
Potential for release from plastics	Molecular weight: 362.50 g/mol, boiling point: 393 °C at 1.013 hPa, vapour pressure: 0.0000009 hPa at 25 °C, partition coefficient (log value) log P_{ow}: 6.9 at 25 °C [Sigma-Aldrich 2014d]. Not chemically bound and will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (analogy considerations to DEHP - see section 3.9.7). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	Exposure is primarily related to soft/flexible PVC products incl. PVC packaging, secondly to polyurethane and scarcely acrylics. All types of phthalate plasticisers will migrate from the soft PVC as they are not chemically bound and as they are fairly low molecular weight plasticisers. They are also all of them added in rather high amounts to PVC (up to 50 % w/w or occasionally even more). The migration tendency depends on the solubility parameter of the phthalate (The partition coefficient Kow is a good estimate), the concentration and the temperature as well as the vapour pressure and the way the exposure takes place (inhalation, orally or by contact with the skin). In the case of packaging for food it will especially be the migration to fatty food which might cause a major contamination of the food (e.g. vegetable oils).
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the high boiling point. By feed stock recycling and energy recovery in incineration plants the phthalates will be decomposed.

Substance	1,2-Benzenedicarboxylic acid, di-C6-8-branched alkyl esters, C7-rich (Diisoheptylphthalat)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_echa_cmr_DIHP_en.pdf Sigma-Aldrich 2014d. Diisoheptyl phthalate - Material Safety Data Sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=376671&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DCAS%2520No.%26term%3D71888-89-6%26lang%3Den%26region%3DDK%26focus%3Dproduct%26N%3D220003048%2B219853103%2B219853286%26mode%3Dpartialmax

3.9.3 Alkanes, C10-13, chloro (Short Chain Chlorinated Paraffins-SCCP)

Substance	Alkanes, C10-13, chloro (Short Chain Chlorinated Paraffins-SCCP)
CAS Number	85535-84-8; 108171-26-2, 287-476-5
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (SVHC); CMR.
Function	Secondary plasticiser and flame retardant [US EPA, 2009a].
Relevant types of plastics	In USA use in PVC is important [US EPA 2009a]. According to [POPRC, 2007] it is not used in PVC in Europe, but primarily in rubber and elastomers (sealants etc.). Use in textile fibres cover cellulosic textiles and in other polymers.
Main article groups	Polyurethane and acrylic sealants. Fire proofing of cellulosic textiles and in other polymers. [POPRC, 2007].
Potential for release from plastics	Will not bind to the polymer matrix. Will migrate and leach/evaporate from plastic. A release factor for medium chained CPs to water for outdoor use in sealants of 0.15 % per year over the 20-to 30-year lifetime of sealants is assumed [POPRC, 2007]. A higher release factor must be assumed for short chained CP. Wear and tear will cause release also.
Potential for exposure of consumers	As the substance is used both as a flame retardant and secondary plasticiser it will be present in plastic products in rather high amounts. For this reason there will be a risk for exposure if used in consumer products as the substance group is not chemical bound to the polymer. SCCP is a liquid with • boiling point: >200 °C; • water solubility: 0.15 -0.47 mg/l: • Log $P_{o/w}$: 4.4-8.7.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the low release factor. By energy recovery in an incineration plant the substance will be decomposed. The content of chlorine may add to formation of dioxins and HCl in the chimney system.

Substance	Alkanes, C10-13, chloro (Short Chain Chlorinated Paraffins-SCCP)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_uk_pbt_sccp_20083006_en.pdf OSPAR (2009b). Background Document on short chain chlorinated paraffins. OSPAR Commission. http://www.ospar.org/documents/dbase/publications/p00397_sccp%20update2.pdf POPRC (2007). Draft risk profile for Short-chained chlorinated paraffins. Persistent Organic Pollutants Review Committee. http://www.pops.int/documents/meetings/poprc/drprofile/drp/DraftRiskProfile_SCCP.pdf US EPA (2009a). Short-Chain Chlorinated Paraffins Action Plan. http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/sccps_ap_2009_1230_final.pdf

3.9.4 Medium-chain chlorinated paraffins (MCCP)

Substance	Medium-chain chlorinated paraffins (MCCP)
CAS Number	85535-85-9
Justification	Danish list of undesired substances; Norwegian priority list.
Function	Plasticiser and flame retardant [KLIF, 2010].
Relevant types of plastics	Soft plastic, PVC, and polyester [KLIF, 2010].
Main article groups	Polyester e.g. in lifeboats. PVC - mainly wallpapers, floor coverings, cables, leisure and travel articles, [KLIF, 2010; NG 2010].
Potential for release from plastics	The substance is not chemically bound and will migrate. MCCP is a liquid with boiling point: > 200 °C, water solubility: 0.005-0.0027 g/l and log $P_{o/w}$: 5.52 – 8.21. MW range: 208 – 825 g/mol. In a risk assessment it is estimated that significant release will take place during in-service life of MCCP in plastics [Annex XV report]. A release factor for medium chained CPs to water for outdoor use in sealants of 0.15% per year over the 20-to 30-year lifetime of sealants is assumed [POPRC, 2007].
Potential for exposure of consumers	As the substance is used both as a flame retardant and secondary plasticiser it will be present in plastic products in rather high amounts. For this reason there will be a risk for exposure if used in consumer products as the substance group is not chemical bound to the polymer.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the low release factor. By energy recovery in an incineration plant the substance will be decomposed. The content of chlorine may add to formation of dioxins and HCL in the chimney system.

Substance	Medium-chain chlorinated paraffins (MCCP)
References	Annex XV Restriction Report http://echa.europa.eu/documents/10162/13630/trd_uk_mccp_en.rtf KLIF (2010). Prioriterte miljøgifter i produkter - data for 2008. Klima- och forurensningsdirektoratet. Oslo. http://www.klif.no/publikasjoner/2743/ta2743.pdf NG (2010). Impact assessment of regulation of medium-chain chlorinated paraffins C14-17 (MCCPs) in consumer products. http://www.eftasurv.int/media/notification-of-dtr/2010-9018-en.pdf POPRC (2007]. Draft risk profile for Short-chained chlorinated paraffins. Persistent Organic Pollutants Review Committee. http://www.pops.int/documents/meetings/poprc/drprofile/drp/DraftRiskProfile_SCCP.pdf

3.9.5 Bis(2-methoxyethyl) phthalate (DMEP)

Substance	Bis(2-methoxyethyl) phthalate (DMEP)
CAS Number	117-82-8
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVHC); CMR.
Function	Plasticiser [Annex XV dossier].
Relevant types of plastics	Nitrocellulose, acetyl cellulose, polyvinyl acetate, polyvinyl chloride and polyvinylidene chloride (globally) [Annex XV].
Main article groups	Uses that have been reported include material to cover floors, balls for playing and exercise, hoppers and children's toys (e.g. as inflatable water products), cellulose acetate lamination films and laminated documents .There is no information whether the substance is still in use in articles on the EU market .[Annex XV dossier].
Potential for release from plastics	Molecular weight: 282.29 g/mol, boiling point: 340 °C (pressure not indicated), vapour pressure: 0.00028 mm Hg at 25 °C, partition coefficient (log value) log P_{ow}: 1.11. Not chemically bound. Will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (estimated based on [ECB 2008]). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	It is judged that the exposure for DMEP is rather limited as the use of the plasticiser is limited to plastics with low consumption (nitrocellulose, acetylcellulose and PVA). The use in PVC and PVDC is considered low, but no actual figures for the consumption in Europe are known. The rules for migration are the same as for the other phthalates. However this phthalate is more polar than the traditional ones. This is the reason for its use in polar plastics like the cellulose based.
Fate of the substance by recycling	Same fate as for diisoheptylphthalate (see section 3.9.2). The most likely recycling is by energy recovery in incineration plants.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_bis2-methocxyethylphthalate_20110829_en.pdf

3.9.6 Benzyl butyl phthalate (BBP)

Substance	Benzyl butyl phthalate (BBP)
CAS Number	85-68-7
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVHC, restriction); List of CMR substances in toy.
Function	Plasticiser [Annex XV].
Relevant types of plastics	BBP is or has been widely used in PVC (60% of all BBP use) [Annex XV]. Other plastics include polymetamethylacrylate (PMMA), polyamide, and thermoplastic polyester [Swedish Chemicals Agency, 2007].
Main article groups	PVC flooring (largest single use category, 41% of the total use volume); Also tablecloth, curtains, shower curtains and other uses. Also sealants (based on polyurethane based or acrylic-based); and other products. [Annex XV].
Potential for release from plastics	Molecular weight: 312.35 g/mol, boiling point: 370°C at 10.10 hPa, vapour pressure: 0.00112 Pa at 20°C, partition coefficient (log value) log P_{ow}: 4.84 [Annex XV dossier]. Not chemically bound. Will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (analogy considerations to DEHP – see section 3.9.7). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	Same considerations as for diisoheptylphthalate (see section 3.9.2)
Fate of the substance by recycling	Same fate as diisoheptylphthalate (see section 3.9.2)
References	Annex XV report http://echa.europa.eu/documents/10162/13640/svhc_axvrep_austria_cmr_bbp_20083006_en.pdf Swedish Chemicals Agency (2007). Varuguiden. (Article guide) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx

3.9.7 Bis (2-ethylhexyl)phthalate (DEHP)

Substance	Bis (2-ethylhexyl)phthalate (DEHP)
CAS Number	117-81-7
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (SVHC, restriction); List of CMR substances in toy.
Function	Plasticiser [Annex XV dossier].
Relevant types of plastics	PVC (mainly), but also other polymer products [Annex XV dossier] e.g. polymetamethylacrylate (PMMA), acrylonitrile-butadiene-styrene (ABS) (0-5 %), polyamide, polystyrene (0-5 %), PVC (0-50 %) and thermoplastic polyester [Swedish Chemicals Agency, 2007].
Main article groups	DEHP has for many years been one of the dominant plasticisers for flexible PVC and used in almost all kind of products made of flexible PVC.

Substance	Bis (2-ethylhexyl)phthalate (DEHP)
Potential for release from plastics	Molecular weight: 390.6 g/mol, boiling point: 385 °C at 1013 hPa, vapour pressure: 0.000034 Pa at 20°C, partition coefficient (log value) log P_{ow}: 7.5 [Annex XV dossier]. Not chemically bound. Will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (estimate based on [ECB 2008]). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	Same considerations as for diisoheptylphthalate (see section 3.9.2). DEHP is expected still to be one of the phthalates of high concern as it still is found in a number of consumer products worldwide.
Fate of the substance by recycling	Same as for diisoheptylphthalate (see section 3.9.2)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_sweden_cmr_DEHP_20083006_en.pdf ATSDR 2012d. Toxicological Profile for DEHP. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service: www.atsdr.cde./toxprofiles/index.asp ECB (2008). EU Risk Assessment Report - bis(2-ethylhexyl)phthalate (DEHP). European Chemicals Bureau (ECB). Swedish Chemicals Agency (2007). Varuguiden. (Article guide) Database. https://webapps.kemi.se/varuguiden/VarugrupperAmne.aspx.

3.9.8 Di (2-ethyl-hexyl) terephthalate (DEHT)

Substance	Di (2-ethyl-hexyl) terephthalate (DEHT)
CAS Number	6422-86-2
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	DEHP-applications.
Potential for release from plastics	Molecular weight: 390.56 g/mol, boiling point: 400 °C, vapour pressure: 1 mmHg at 217 °C, log P_{ow}: no data available [Sigma-Aldrich 2014f]. Not solid bound and will migrate due to e.g. low molecular weight and medium high boiling point (characteristics similar to DEHP (see section 3.9.7)).
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes.

Substance	Di (2-ethyl-hexyl) terephthalate (DEHT)
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma-Aldrich 2014f. Dioctyl terephthalate - Material Safety Data Sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=525189&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Faldrich%2F525189%3Flang%3Den

3.9.9 Dibutyl phthalate (DBP)

Substance	Dibutyl phthalate (DBP)
CAS Number	84-74-2
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVHC, restriction); List of CMR substances in toy.
Function	Plasticiser [Annex XV dossier], component in catalyst for PP (several internet sources).
Relevant types of plastics	PVC (plasticiser) [Annex XV dossier], PP (catalyst). Today extensively used to plasticise PVA-based adhesives and as plasticiser-solvent for nitrocellulose lacquers and similar [Gooch 2010, DBP Information Centre 2012].
Main article groups	DBP has for many years been one of the dominant plasticisers for flexible PVC and used in many products made of flexible PVC. DBP is used for producing flexible plastics that are part of many products for both industrial and consumer use. These include flooring, balls, products, footwear, articles like tablecloth, shower curtains etc. [Hansen et al, 2010].
Potential for release from plastics	Molecular weight: 278.34 g/mol, boiling point: 340°C at 10.013 hPa, vapour pressure: 9.7 ± 3.3 x 10-5 Pa at 25 °C, partition coefficient (log value) log P_{ow}: 4.57 at 20°C [Annex XV dossier]. Not chemically bound. Will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (analogy considerations to DEHP – see section 3.9.7). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	As for diisoheptylphthalate (see section 3.9.2)
Fate of the substance by recycling	Same fate as diisoheptylphthalate (see section 3.9.2)

Substance	Dibutyl phthalate (DBP)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_austria_cmr_dbp_20083006_en.pdf DBP information Centre (2012). DBP-A speciality stabilizer. DBP - A speciality plasticiser. http://www.dbp-facts.com/index.asp?page=1 (Nov. 2012). Gooch, J.W. (2010). Encyclopaedic Dictionary of Polymers, Volume 1, 2nd edition, Springer. Hansen E., Maag J., Høibye L. (2010). Background data for Annex XV dossier - DEHP - SEE SECTION 3.9.7, BBP, DBP and DIBP. Environmental report No. 1362/2011. Danish Environmental Protection Agency. Hansen E., Christensen C.L., Høibye L. (2008). Forbrug af ftalater i Danmark i historisk perspektiv. Miljøstyrelsen, Danmark.

3.9.10 Diisobutyl phthalate (DiBP)

Substance	Diisobutyl phthalate (DiBP)
CAS Number	84-69-5
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVCH, restriction); CMR.
Function	Specialist plasticiser, gelling aid in combination with other plasticisers, plasticiser for nitrocellulose, cellulose ether (which are cellulosic plastic) and polyacrylate and polyacetate dispersions [Annex XV dossier].
Relevant types of plastics	PVC, polystyrene [Gooch, 2010], nitrocellulose, cellulose ether (which are cellulosic plastic) and polyacrylate and polyacetate dispersions [Annex XV dossier].
Main article groups	DiBP has application properties similar to DBP, and may thus be used in all products, where DBP is used. DiBP has been registered in products like crayons, bar ends of run bikes, erasers, school bags, plastic spoons and forks, boxes for microwave ovens, milk package bags, spoons, cups, plates and bowls [Annex XV dossier]. In many products DiBP may not be used intentedly and is present due to contamination.
Potential for release from plastics	Molecular weight: 278.35 g/mol, boiling point: 320 °C, vapour pressure: 0.01 Pa at 20 °C, partition coefficient (log value) log P_{ow}: 4.11 [Annex XV dossier]. The substance is not chemically bound and will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (analogy considerations to DEHP – see section 3.9.7). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance.
Potential for exposure of consumers	As for diisoheptylphthalate (see section 3.9.2)
Fate of the substance by recycling	Same fate as diisoheptylphthalate (see section 3.9.2)

Substance	Diisobutyl phthalate (DiBP)
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_germany_cmr_diisobutylphthalate_20090831_en.pdf Gooch, J.W. (2010). Encyclopaedic Dictionary of Polymers, Volume 1, 2nd edition, Springer.

3.9.11 Other phthalates

Substance	Di-"isononyl" phthalate (DINP), Di-"isodecyl" phthalate (DIDP), Bis(2-propylheptyl) phthalate (DPHP), Diethyl phthalate (DEP),Diisopentyl phthalate (DIPP), Dihexyl phthalate (DHP), Dicyclohexyl phthalate, Diisohexyl phthalate
CAS Number	68515-48-0/28553-12-0, 68515-49-1/26761-40-0, 53306-54-0, 84-66-2, 605-50-5, 84-75-3 84-61-7, 68515-50-4.
Justification	DINP, DIDP, DPHP and DEP are surveyed as part of the work with the Danish list of undesired substances, Registry of intentions (CLP, SVHC); CMR.
Function	Plasticiser
Relevant types of plastics	PVC and other plastic materials including polyvinyl acetate, cellulose plastics and PUR [Chemicalland21 – DHP].
Main article groups	Plasticised articles including PVC floorings and wall coverings, expanded leather, PVC foams, films, polyurethane sealing/adhesive [Chemicalland21 – DHP].
Potential for release from plastics	Same as for diisoheptylphthalate (see section 3.9.2)
Potential for exposure of consumers	Same as for diisoheptylphthalate (see section 3.9.2)
Fate of the substance by recycling	Same fate as for diisoheptylphthalate (see section 3.9.2)
References	Chemicalland21 – DHP. Dihexyl phthalate. http://www.chemicalland21.com/industrialchem/plasticizer/DIHEXYL%20PHTHALATE.htm (Nov. 2013) CLH report – DIHP (2013). Diisohexyl phthalate. http://echa.europa.eu/documents/10162/a062e3f3-80b9-4e90-9848-dd73c42764df (Nov. 2013) Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency.

3.9.12 Tributyl phosphate

Substance	Tributyl phosphate
CAS Number	126-73-8
Justification	List of CMR-substances in toy.
Function	Plasticiser.

Substance	Tributyl phosphate
Relevant types of plastics	Cellulose based plastics. Various plastics.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 266.3141 g/mol, boiling point: 289 °C (decomposes), vapour pressure: 0.003 mm Hg at 25 °C, partition coefficient (log value) log P_{ow}: 4 [ECHA 2012a]. Not solid bound and will migrate due to e.g. low molecular weight and medium high boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the medium/high boiling point.
References	ATSDR (2012e). Toxicological Profile for Phosphate Ester Flame Retardants. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health and Human Services, Public Health Service. www.atsdr.cde./toxprofiles/index.asp ECHA (2012a). Substance evaluation report – Tributyl phosphate. http://echa.europa.eu/documents/10162/3f703a8f-bbf9-4b69-8fbb-8eb69ca46467 Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.9.13 Sulfonic acids, C10 – C18-alkane, phenylesters

Substance	Sulfonic acids, C10 – C18-alkane, phenylesters (ASE)
CAS Number	91082-17-6
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	DEHP applications.
Potential for release from plastics	Molecular weight: Not applicable [Santa Cruz 2010], melting point: -15 °C (decomposes by heating), vapour pressure: < 0.0001 hPa at 20 °C, log P_{ow}: > 6 [Sigma-Aldrich 2104e]. Not solid bound and will migrate due to e.g. low melting point.
Potential for exposure of consumers	Possible risk to exposure based on the chemical structure and low molecular weight (MW). The MW range is judged from the molecular formulas for the sulphonic acid esters and not from the statement in the MDS above.
Fate of the substance by recycling	It is unclear to what extent the substance will remain in the plastic materials by mechanical recycling. The substance may partly evaporate and decompose by mechanical recycling.

Substance	Sulfonic acids, C10 – C18-alkane, phenylesters (ASE)
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Santa Cruz (2010). Alkylsulfonic phenyl ester - Material Safety Data Sheet http://datasheets.scbt.com/sc-253001.pdf Sigma-Aldrich (2014e). Mesamoll® - Material Safety Data Sheet http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=50987&brand=FLUKA&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fsearch%3Finterface%3DCAS%2520No.%26term%3D91082-17-6%26lang%3Den%26region%3DDK%26focus%3Dproduct%26N%3D220003048%2B219853103%2B219853286%26mode%3Dpartialmax

3.9.14 Acetyl tributyl citrate (ATBC)

Substance	Acetyl tributyl citrate (ATBC)
CAS Number	77-90-7
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Some DEHP-applications.
Potential for release from plastics	Molecular weight: 402.49 g/mol, boiling point: 326°C at 760 mm Hg, vapour pressure: 5.2 x 10^{-2} mm Hg at 20 °C, log P_{ow}: 4.92 at 22°C [US EPA 2003]. Not solid bound and will migrate due to e.g. low molecular weight and medium high boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	It is judged that the substance mainly will remain in the plastic by mechanical recycling due to the medium high boiling point.
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. US EPA (2003b). Acetyl Tributyl Citrate – Appendix. Robust Summaries of Reliable Studies and QSAR Model Data. http://www.epa.gov/hpv/pubs/summaries/acetlcit/c15025rs.pdf

3.9.15 Mixture of benzoates incl. DEGD

Substance	Mixture of benzoates incl. DEGD
CAS Number	Mix of 120-55-8, 27138-31-4, 120-56-9
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Vinyl flooring, plastisol products, DBP- and BBP-applications and some DEHP applications.
Potential for release from plastics	DEGD (CAS no.: 120-55-8): Molecular weight: 314.34, melting point. -28°C, boiling point: decomposes at > 230°C without boiling, vapour pressure: 0.0000173 Pa at 25 °C, log P_{ow}: 3.2 [Velsicol 2001]. Not solid bound and will migrate due to e.g. low molecular weight and melting point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C). The substance may, however, partly evaporate during the process.
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Velsicol (2001). Diethylen glycol dibenzoate - Robust Summary http://www.epa.gov/hpv/pubs/summaries/diglydib/c13271.pdf

3.9.16 Mixture of 12-(Acetoxy)-stearic acid, 2,3-bis(acetoxy)propyl ester and octadecanoic acid, 2,3-(bis(acetoxy)propyl ester (COMGHA)

Substance	Mixture of 12-(Acetoxy)-stearic acid, 2,3-bis(acetoxy)propyl ester and octadecanoic acid, 2,3-(bis(acetoxy)propyl ester (COMGHA)
CAS Number	Mix of 330198-91-9 and 33599-07-4
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Plastisol applications, traditional DEHP-applications (see section 3.9.7).
Potential for release from plastics	Molecular weight: 500.7 (A) and 442.6 (B) g/mol, boiling point: 300°C at 1 atm (decomposition), vapour pressure: < 2.8 x 10-4 Pa at 100°C, log P_{ow}: 6.4 (measured) [SCENIHR 2007]. Not solid bound and will migrate due to e.g. low molecular weight and medium high boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).

Substance	Mixture of 12-(Acetoxy)-stearic acid, 2,3-bis(acetoxy)propyl ester and octadecanoic acid, 2,3-(bis(acetoxy)propyl ester (COMGHA)
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. SCENIHR 2007. Preliminary report on the safety of medical devices containing DEHP plasticised PVC or other plasticisers on neonates and other groups possibly at risk. EC Scientific Committee on Emerging and Newly-Identified Health Risks. http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_008.pdf

3.9.17 Diisononyl adipate (DINA)

Substance	Diisononyl adipate (DINA)
CAS Number	33703-08-1
Justification	List of alternative plasticisers
Function	Plasticiser
Relevant types of plastics	PVC etc.
Main article groups	Film/wrapping – low temperature applications
Potential for release from plastics	Molecular weight: 398.62 g/mol, melting point: 225°C, boiling point: 405.8°C at 760 mmHg, vapour pressure: < 0.1 mbar at 20 °C, water solubility: Slightly soluble [Ark Fram 2013; Chemexper 2014]. Not solid bound and will migrate due to e.g. low molecular weight and medium high melting and boiling points similar to other adipates.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).
References	Ark Farm (2013). Bis(7-methyloctyl) adipate – MSDS. http://www.chemblink.com/MSDS/MSDSFiles/33703-08-1_Ark%20Pharm.pdf Chemexper (2014). Diisononyl adipate – MSDS. http://www.chemexper.net/specification_d/chemicals/supplier/cas/Diisononyl%20adipate.asp Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency.

3.9.18 Diisononyl-cyclohexane-1,2-carboxylate (DINCH)

Substance	Diisononyl-cyclohexane-1,2-carboxylate (DINCH)
CAS Number	166412-78-8
Justification	List of alternative plasticisers

Substance	Diisononyl-cyclohexane-1,2-carboxylate (DINCH)
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Toys and childcare articles, general plasticiser applications.
Potential for release from plastics	Molecular weight: 424.7 g/mol, pour point: - 54°C, boiling point: 394°C at 1013 hPa (decomposes > 278 °C), vapour pressure: < 0.000001 hPa at 20 °C, partition coefficient (log value) log P_{ow}: 10 at 25 °C [Evonik 2013]. Not solid bound and will migrate due to e.g. low molecular weight and pour point and medium high boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).
References	Evonik (2013). Elatur ®CH- Material Safety Data Sheet. http://oxo-alcohols.evonik.com/sites/dc/Downloadcenter/Evonik/Product/Oxo-Alcohols/en/safety-data-sheet-elatur%C2%AE-ch.pdf Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.9.19 Dipropylene glycol dibenzoate (DGD)

Substance	Dipropylene glycol dibenzoate (DGD)
CAS Number	27138-31-4
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Flooring etc., PVA-adhesives.
Potential for release from plastics	Molecular weight: 342.39 g/mol [Sigma-Aldrich 2014g], boiling point: 232 °C at 7 hPa, vapour pressure: 2.3 x 10^{-7} mmHg at 20 °C [Unitex 2008], log P_{ow}: no data available [Sigma-Aldrich 2014g]. Not solid bound and will migrate due to e.g. low molecular weight and medium boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).

Substance	Dipropylene glycol dibenzoate (DGD)
References	Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J.(2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma-Aldrich 2014g. Di(propylene glycol) dibenzoate - Material Satefy Data Sheet. http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=DK&language=da&productNumber=597236&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Faldrich%2F597236%3Flang%3Den Unitex (2008). Dipropylene Glycol Dibenzoate – MSDS. http://www.unitexchemical.com/MSDS_CURR/UPLX988_MSDS.pdf

3.9.20 Glycerol triacetate (GTA)

Substance	Glycerol triacetate (GTA)
CAS Number	102-76-1
Justification	List of alternative plasticisers.
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	PVA-adhesives, coatings.
Potential for release from plastics	Molecular weight: 218.206 g/mol, melting point: 3 °C, boiling point: 258 °C, vapour pressure: 0.33 torr at 25 °C, log P_{ow}: 0.25 at 25 °C [California EPA]. Due to the low molecular weight, low melting point, medium boiling point and chemical structure it is judged that GTA will migrate in a similar manner to the phthalate plasticisers.
Potential for exposure of consumers	Exposure similar to the phthalates is foreseen due to the low molecular weight and ester structure.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).
References	California EPA. Substance Database. California Environmental Protection Agency. http://www.arb.ca.gov/db/solvents/solvent_pages/esters-HTML/glyceryl_triacetate.htm Mikkelsen S. H., Maag J., Kjolholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.9.21 Trimethyl pentaryl diisobutyrate (TXIB)

Substance	Trimethyl pentaryl diisobutyrate (TXIB)
CAS Number	6846-50-0
Justification	List of alternative plasticisers.

Substance	Trimethyl pentaryl diisobutyrate (TXIB)
Function	Plasticiser.
Relevant types of plastics	PVC etc.
Main article groups	Toys, childcare products.
Potential for release from plastics	Molecular weight: 286.4 g/mol, melting/freezing point: -70 °C, boiling point: 281.5 °C, vapour pressure: < 1.5 Pa at 25 °C, partition coefficient (log value) log P_{ow}: 4.04 - 4.91 [Eastman 2014; LookChem 2008]. Not solid bound and will migrate due to e.g. low molecular weight and melting point and medium high boiling point.
Potential for exposure of consumers	Possible.
Fate of the substance by recycling	The substance will mainly remain in the plastic by mechanical recycling due to the low temperature in the mechanical recycling processes for flexible PVC (150-170 °C).
References	Eastman (2014). 2,2,4-trimethyl-1,3-pentanediol diisobutyrate - Material Safety Data Sheet http://ws.eastman.com/ProductCatalogApps/PageControllers/MSDS_PC.aspx?Product=71066420 LookChem (2008). 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate. http://www.lookchem.com/cas-684/6846-50-0.html (May 2014) Mikkelsen S. H., Maag J., Kjølholt J., Lassen C., Jeppesen C. N., Clausen A.J. (2013). Survey of selected phthalates - Part of the LOUS-review. Danish Environmental Protection Agency.

3.10 Solvents –neutral and reactive

Neutral solvents are typically used early in the polymerisation processes to assist the reactive monomers to get in close contact by dissolving them in the process. At the same time they function as a viscosity adjuster/reducer. Neutral solvents are also used in adhesives to glue the different plastics in the laminate together.

Reactive solvents both act as a viscosity reducer at the beginning of the polymerization processes and as reactive monomer.

Solvents are generally only present in low concentrations in plastic products because they are used as intermediates at an early stage in the polymerisation process for the plastic raw polymer and often have fairly low molecular weights and boiling points. They will thus typically evaporate fast resulting in that solvents are not likely to be present in plastic by the end of in-service life and thus not present in recycled materials.

Another reason for the common judgement that the solvents will only be present in low concentrations in finished plastic products is that for all thermoplastic processes these take place at high temperatures which means that volatile solvents will evaporate in the manufacturing process.

Only for the thermosetting plastics there is a higher risk that reactive solvents can be present either because of bad mixing in the thermosetting cure process or faulty mixing ratio of the reactive monomers and the catalysts.

No general rules exist for the amount of solvents used in manufacturing of polymers and plastics.

It should be noted that styrene (see section 3.6.14) and butyl 2,3-epoxypropyl ether, butyl glycidyl ether (see section 3.6.20) will also function as solvents being chemical intermediates in the manufacturing of plastics.

3.10.1 2-Methoxyethanol

Substance	2-Methoxyethanol
CAS Number	109-86-4
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Solvent, chemical intermediate and solvent coupler of mixtures and water-based formulations [Annex XV report]. Solvent in epoxy resins and polyvinylacetate [Chemindustry.ru, 2000-2010; OSHA, 2012].
Relevant types of plastics	Epoxy resins and polyvinylacetate. The knowledge available is poor.
Main article groups	Not specified. Plastic products made of epoxy or polyvinylacetate. Emissions from new carpets have been registered. The knowledge available is poor.
Potential for release from plastics	The substance is not chemical bound (a solvent) and volatile (molecular weight: 76.09 g/mol, boiling point: 123.5 – 125.5 °C at 1013 hPa, vapour pressure: 10 hPa at 20°C, log P_{ow}: 0.77 (calculated -0.85)) and will likely migrate easily.
Potential for exposure of consumers	It is judged that there will be a high risk for exposure if the substance is still present in the plastic products due to low molecular weight and boiling point. It is at the same time judged that the amount left in the plastic products is low as the solvent is used in an early stage of PVC raw polymer formulation. The strong evaporation of the substance means that occupational exposure may be given special attention.

Substance	2-Methoxyethanol
Fate of the substance by recycling	The substance is expected to evaporate before the plastic product is discarded as waste at the "end of life stage". The substance will most likely not be present in recycled materials.
References	Annex XV report (2010). http://echa.europa.eu/documents/10162/b6b959c2-14c8-4612-9e91-cf181a867dd2 Chemindustry.ru. (2000-2010). 2-methoxyethanol. http://chemindustry.ru/Methyl_Cellosolve.php Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April. 2014. OSHA (2012). Occupational Safety and Health Administration. http://www.osha.gov/SLTC/healthguidelines/2-ethoxyethanol/recognition.html

3.10.2 Trichloroethylene

Substance	Trichloroethylene
CAS Number	79-01-6, 108-70-3,
Justification	Norwegian priority list; Candidate list. Registry of intentions (SVHC); CMR.
Function	Intermediate or chain transfer agent for controlling molecular weight in the early stages of PVC manufacturing [Hocking 2005; Annex XV report]. According to the EU [2004] Risk assessment report it is "apparently" no longer used as a chain transfer agent (however no information to confirm this statement has been found).
Relevant types of plastics	PVC.
Main article groups	Not specified - probably all product types.
Potential for release from plastics	Molecular weight: 131.39 -131.5 g/mol, boiling point: 85.9 to 88 °C, vapour pressure: 78.7 to 86 hPa at 20°C, partition coefficient (log value) log P_{ow}: 2.29 to 2.98 [Annex XV dossier]. Very volatile. Will easily migrate and evaporate. Most of the substance will likely disappear from the products, when they still are new.
Potential for exposure of consumers	It is judged that there will be a high risk for exposure if the substance is still present in the plastic due to low molecular weight and boiling point. However it is at the same time judged that the substance typically will be present in low concentrations only as it is used as an intermediate early in the PVC polymerisation. The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	The substance is expected to have evaporated before the" end of life plastic stage". The substance will most likely not be present in recycled materials.

Substance	Trichloroethylene
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_france_cmr_trichloroethylene_en.pdf EU (2004). European risk assessment report. Trichloroethylene CAS no. 79-01-6. http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/trichloroethylenereport018.pdf Hocking (2005). Handbook of Chemical Technology and Pollution Control, 3rd Edition, Academic press, San Diego. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.10.3 N,N-dimethylformamide (DMF)

Substance	N,N-dimethylformamide (DMF)
CAS Number	68-12-2
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVHC); List of CMR substances in toy.
Function	Chemical intermediate/solvent.
Relevant types of plastics	polyacrylonitrile, polyurethane and polyvinylchloride.
Main article groups	Artificial fibres/artificial leather.
Potential for release from plastics	Molecular weight: 73.0938 g/mol, boiling point: 152-153°C at 1013 hPa, vapour pressure: 3.77 hPa at 20°C, partition coefficient (log value) log P_{ow}: -0.85 at 25°C [Annex XV dossier]. As a solvent it might evaporate and migrate. And as the DMF is very polar, it must be foreseen to migrate to contact medias containing water (e.g. sweat). The amount of DMF left in the plastic is however considered low.
Potential for exposure of consumers	If present it is judged that there is a high risk for exposure due to rather low molecular weight and boiling point but at the same time it is judged that the substance typically is present in low concentrations only. The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	The substance is expected to evaporate before product is discarded as waste at the" end og life stage". If still present at the "end of life stage" it is judged that the substance will be dissolved in the washing process due to the high solubility in water. The substance will most likely not be present in recycled materials. Substances used in thermosetting materials as polyurethane will be decomposed by feedstock recycling as well as energy recovery.
References	Annex XV dossier – DMF. N,N-dimethylformamide. http://echa.europa.eu/documents/10162/13638/SVHC_ACCCHECK_AXVREP_pub_EC200-679-5_en.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.10.4 1,2,3-Trichloropropane

Substance	1,2,3-Trichloropropane
CAS Number	96-18-4
Justification	Candidate list; Registry of intentions (SVHC); CMR.
Function	Intermediate - Crosslinking agent [Annex XV dossier].
Relevant types of plastics	Hexafluoropropylene [Annex XV dossier] which is used as a copolymer with e.g. tetrafluoroethylene and polyvinylidenefluoride (elastomer).
Main article groups	Tetrafluoroethylene-Hexafluoropropylene-Copolymer (FEP) is used: • for the manufacture of heating cables for chemical platoon; • for the manufacture of heating tapes; • in foils; • in filaments and cables at communications; • in injection moulded components; and • in coating for valves, tubes, vessels and tanks [Mecadi, GmbH, 2012].
Potential for release from plastics	Molecular weight: 147.4 g/mol, boiling point: 157 °C at 1013 hPa, vapour pressure: 10 hPa at 37 °C, partition coefficient (log value) log P_{ow}: 2.5[Annex XV dossier]. Solid bound due to crosslinking (reactive) behaviour. Residues (Molecular weight: 147.4 g/mol, boiling point: 157 °C at 1013 hPa - Volatile) will migrate and slowly evaporate from the plastic.
Potential for exposure of consumers	If the substance is still present after cure by crosslinking it is judged that a high risk exist for exposure due to rather low molecular weight and boiling point. It is judged that the substance typically will be present in low concentrations in the finished plastic products. The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	The substance is expected to evaporate before the plastic product is discarded as waste at the "end of life stage". The substance will most likely not be present in recycled materials.
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_echa_cmr_123-tcp_publ_en.pdf Meade GmbH. (2012). webpage: http://www.mecadi.com/en/literature_tools/encyclopedia/categorial/Thermoplastic/Tetrafluoroethylene-Hexafluoropropylene-Copolymer_FEP/ Nilsson N. (2014). Expert assessment by Nils Nilsson, Danish Technological Institute, Århus, April 2014

3.10.5 1,6-hexanediol diglycidyl ether

Substance	1,6-hexanediol diglycidyl ether
CAS Number	16096-31-4
Justification	Danish list of undesired substances
Function	Reactive dilutant, stabiliser.
Relevant types of plastics	Epoxies, chlorinated vinyl resins.
Main article groups	No information.

Substance	1,6-hexanediol diglycidyl ether
Potential for release from plastics	Molecular weight: 230.3 g/mol, boiling point: 328.7 °C, vapour pressure: 0.002 mg Hg, partition coefficient (log value) log P_{ow}: 0.84. Low according to one of the manufacturers (DOW). Due to the two epoxide groups the substance is very reactive and if a small amount is left after cure it is expected that the epoxide groups will hydrolyse in the presence of water and the epoxide ring will open and react with water with the formation of hydroxyl groups.
Potential for exposure of consumers	Considered rather unlikely due to the high reactivity of the two oxirane rings.
Fate of the substance by recycling	The substance is judged to be present in very low amount due to the high reactivity of the oxirane rings in the end of life stage for the resins. Substances used in thermosetting materials as epoxies will be decomposed by feedstock recycling as well as energy recovery.
References	Hansen E., Christensen F.M., Kjølholt J., Jeppesen C.N., Lassen C. (2012a). Survey of 1,6-hexandioldi-glycidylether - A LOUS Review Report. Danish Environmental Protection Agency. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.10.6 Dichloromethane, methylene chloride

Substance	Dichloromethane, methylene chloride
CAS Number	75-09-02
Justification	List of CMR-substances in toy.
Function	Intermediate.
Relevant types of plastics	Polycarbonate. Has been used as blowing agent for PUR and for gluing PVC together. In Denmark in 1998 only registered in preparations (mould release agents etc.) for moulding of plastic products [Maag 1998].
Main article groups	No information.
Potential for release from plastics	Molecular weight: 84.93 g/mol, boiling point: 40 °C, vapour pressure: 470.8 hPa at 20.0 °C, partition coefficient (log value) log P_{ow}: 1,25 [Sigma-Aldrich 2008]. Probably used as a solvent. Methylene chloride is a very low boiling solvent.
Potential for exposure of consumers	If present in the plastic, it is judged that there will be a high risk for exposure due to the low molecular weight and low boiling point but at the same time, it is judged that the substance typically will be present in low concentrations due to a fast evaporate rate. Dichloromethane used in preparations for moulding of plastic products will evaporate very quickly and not be present in end products. The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	The substance is expected to evaporate before the plastic product is discarded as waste at the “end of life stage”. The substance will most likely not be present in recycled materials.

Substance	Dichloromethane, methylene chloride
References	Maag J. 1998. Massestrømsanalyse for dichlormethan, trichlorethylen og tetrachlorethylen. Environmental project No. 392/1998. Danish Environmental Protection Agency. http://www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/udgiv/Publikationer/1998/87-7909-128-8/html/default.htm Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. Sigma-Aldrich 2008. Dichloromethane - Material Safety Data Sheet http://www.frederiksen.eu/uploads/tx_tcshop/media/862900.pdf

3.10.7 1,1,2-trichloroethane

Substance	1,1,2-trichloroethane
CAS Number	79-00-5
Justification	List of CMR-substances in toy.
Function	Intermediate.
Relevant types of plastics	Teflon.
Main article groups	Tubings etc.
Potential for release from plastics	Molecular weight: 133.40 g/mol, boiling point: 113.7 °C, vapour pressure: 1.0 x 10^4 Pa at 50°C, partition coefficient (log value) log P_{ow}: 2.05 at 25°C [OECD SIDS 2000]. The substance will migrate easily due to the low boiling point and medium high vapour pressure.
Potential for exposure of consumers	If present in the plastic it is judged that there will be a high risk for exposure due to the low molecular weight and low boiling point, but at the same time it is judged that the substance typically will be present in very low concentrations due to evaporation. The strong evaporation of the substance means that it is relevant to give special attention to occupational exposure.
Fate of the substance by recycling	The substance is expected to evaporate before the plastic product is discarded as waste at the "end of life stage". The substance will most likely not be present in recycled materials.
References	Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. OECD SIDS 2000. 1,1,2-Trichloroethane http://www.inchem.org/documents/sids/sids/79005.pdf

3.10.8 1,4-dioxane

Substance	1,4-dioxane
CAS Number	123-91-1
Justification	List of CMR-substances in toy.
Function	Intermediate.

Substance	1,4-dioxane
Relevant types of plastics	Cellulose based polymers (cellulose acetate, ethyl cellulose, benzyl cellulose), polyvinyl polymers etc.
Main article groups	No information.
Potential for release from plastics	Molecular weight: 88 g/mol, boiling point: 101°C, vapour pressure: 40 hPa at 20°C, partition coefficient (log value) log P_{ow}: -0.27 [ECB 2002b]. The substance will migrate easily due to the low boiling point and medium high vapour pressure.
Potential for exposure of consumers	If present in the plastic it is judged that there will be a high risk for exposure due to the low molecular weight and fairly low boiling point but at the same time it is judged that the substance typically will be present in very low concentrations due to evaporation. The strong evaporation of the substance means that occupational exposure may be given special attention.
Fate of the substance by recycling	The substance is expected to evaporate before the plastic product is discarded as waste at the "end of life stage". The substance will most likely not be present in recycled materials.
References	ECB (2002b). 1,4-dioxane -EU Risk Assessment Report. http://echa.europa.eu/documents/10162/a4e83a6a-c421-4243-a8df-3e84893082aa Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.11 Others

The group others cover a number of substances with very different functions, and some of the substances have several functions. They are included in the category of "others", as they are difficult to place in the other categories presented, or their function and application are not well identified.

The functions identified include monomers, stabilizers, dispersing agent, impurity, corrosion inhibitor, buffering agent, and flame retardant.

Migration behaviour differs from solid bound to documented migration. For several of the substances the information available is, however, scarce, and the assessment of their behaviour and fate thus uncertain.

3.11.1 Nonylphenol and its ethoxylates

Substance	Nonylphenol and its etoxylates
CAS Number	104-40-5, 7311-27-5, 9014-90-8, 9016-45-9, 9040-65-7, 9051-57-4, 9081-17-8, 11096-42-7, 25154-52-3, 26027-38-3, 26571-11-9, 27177-03-3, 27177-05-5, 27177-08-8, 27986-36-3, 28987-17-9, 37205-87-1, 51811-79-1, 52503-15-8, 66197-78-2, 68412-54-4, 68584-47-4, 68891-21-4, 72580-36-0, 84852-15-3, 127087-87-0
Justification	Danish list of undesired substances; Norwegian priority list; Candidate list; Registry of intentions (SVHC, restriction); List of CMR substances in toy;
Function	Nonylphenol: Monomer (for phenol/formaldehyde reins), catalyst (in the curing of epoxy resins) [EU Commission, 2003]. Nonylphenol can be reacted to form tris(4-nonyl-phenyl) phosphite (TNPP) an antioxidant (for vinyl, polyolefins, and polystyrenics). TNPP is also used as a stabilizer in plastic food packaging. [US EPA, 2010]. Barium and calcium salts of NP are used as heat stabilizers for polyvinyl chloride (PVC). [US EPA, 2010]. Nonylphenol etoxylates has no use related to plastics. More than half of the tonnage of nonylphenol is used to produce nonylphenol ethoxylates surfactants [EU Commission, 2003].
Relevant types of plastics	Phenol/formaldehyde plastic, epoxy [EU Commission, 2003]. Polyurethane foam (emulsifier), PVC.
Main article groups	No information.
Potential for release from plastics	Molecular weight variates from substance to substance. The following physicochemical properties apply for CAS no.: 104-40-5 and 84852-15-3: Melting point: < -7 °C at 1 atm, boiling point: 302 °C at ca.101 kPa (decomposition may occur), vapour pressure: 0.109 Pa- 0.3 Pa at 25 °C, water solubility: ca. 5.7 -7 mg/l at 25 °C, log K_{ow}: 5.4 – 5.76 [Annex XV dossier]. The substances are not chemically bound and will migrate. Although it does contain residual NP, TNPP has been approved for use in food packaging by the US Food and Drug Administration [US EPA 2010].
Potential for exposure of consumers	Unknown.

Substance	Nonylphenol and its etoxylates
Fate of the substance by recycling	Judged partly to evaporate and partly to remain in the thermoplastic by mechanical recycling. Thermosetting plastics can only be recycled by incineration or by feedstock recycling. In both cases the substances will be decomposed. In Denmark only incineration is practised.
References	Annex XV dossier: 4-Nonylphenol, branched and linear: http://echa.europa.eu/documents/10162/59e6cb9d-f70b-4321-b7b6-557cbddca8da EU Commission (2003). Recommendation from the Scientific Committee on Occupational Exposure Limits for commercial nonylphenol. SCOEL/SUM/103. Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014. OSPAR (2009). Background Document on nonylphenol/nonylphenol ethoxylates. http://www.ospar.org/documents/dbase/publications/p00396_npnpe%20update.pdf RPA (1999). Nonylphenol Risk Reduction Strategy. http://archive.defra.gov.uk/environment/quality/chemicals/documents/nonylphenol_rrs.pdf US EPA (2010). Nonylphenol (NP) and Nonylphenol Ethoxylates (NPEs) Action Plan. http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/RIN2070-ZA09_NP-NPEs%20Action%20Plan_Final_2010-08-09.pdf

3.11.2 Octylphenol and its ethoxylates

Substance	Octylphenol and its ethoxylates
CAS Number	140-66-9, 1806-26-4, 9004-87-9, 9036-19-5, 9063-89-2, 11081-15-5, 68987-90-6, 69011-84-3
Justification	Norwegian priority list; Candidate list.
Function	Octylphenol: Monomer (for phenol formaldehyde resin) - (major use) [UK Environment Agency, 2005]. Antioxidant in stabilizers- (minor use) [RPA 2006]. Octylphenol ethoxylate: Emulsifiers in finishing agents (mainly styrene-butadiene copolymers and PTFE) that cover textiles and leather with a thin film [UK Environment Agency, 2005].
Relevant types of plastics	Phenol formaldehyde resin, PVC, styrene-butadiene copolymer.
Main article groups	OP-based resins are used for secondary insulation of electrical windings (e.g. in motors and transformers) to improve insulation and bond windings together [RPA, 2006]. Articles made of phenol, a polymer finishing that can cover textiles and leather [UK Environment Agency, 2005]. Antioxidant in stabilisers for PVC cable jacketing.

Substance	Octylphenol and its ethoxylates
Potential for release from plastics	CAS no. 140-66-9: Molecular weight: 206.33 g/mol, boiling point: 281.5 °C, vapour pressure: 0.21 Pa at 20°C, log P_{ow}: 4.12 at 20.5°C [RPA (2006)]. Most of the 4-tert-octylphenol in the resins is chemically bound and cannot be released even on subsequent chemical or biological degradation, but the resins may also contain a small proportion (~3-4%) of unreacted 4-tert-octylphenol [UK Environment Agency, 2005]. The octylphenol ethoxylate is physically bound in the polymer matrix [UK Environment Agency, 2005]. The unreacted 4-tert-octylphenol may be released (molecular weight: 206.33 g/mol, boiling point: 281.5˚C) [UK Environment Agency, 2005].
Potential for exposure of consumers	Unknown, but possible for unreacted 4-tert-octylpheno.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the boiling temperature. Some evaporation of unreacted substances may, however, take place. Phenol resins can only be recycled by incineration or by feedstock recycling. In both cases the substance will be decomposed. In Denmark only incineration is practised.
References	RPA (2006). 4-tert-Octylphenol Risk Reduction Strategy and Analysis of Advantages and Drawbacks. http://archive.defra.gov.uk/environment/quality/chemicals/documents/op-rrs-aad-report.pdf UK Environment Agency (2005). Environmental Risk Evaluation, Report: 4-tert-Octylphenol. http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0405biyz-e-e.pdf

3.11.3 Perfluorooctanoic acid (PFOA) and similar compounds

Substance	Perfluorooctanoic acid (PFOA) and similar compounds
CAS Number	15166-06-0, 2395-00-8, 24216-05-5, 3108-24-5, 33496-48-9, 335-64-8, 335-66-0, 335-67-1, 335-93-3, 335-95-5, 376-27-2, 3825-26-1, 39186-68-0, 41358-63-8, 423-54-1, 53517-98-9, 68141-02-6, 68333-92-6, 69278-80-4, 72623-77-9, 72968-38-8, 85938-56-3, 89685-61-0, 90179-39-8, 90480-55-0, 90480-56-1, 90480-57-2, 91032-01-8, 93480-00-3
Justification	Norwegian priority list: Danish list of undesired substances; Candidate list, Registry list of intentions (CLP, SVHC).
Function	Dispersing agent (for production of special plastics e.g. PTFE).
Relevant types of plastics	Polytetrafluorethylene (PTFE) and fluoroethylene propylene (FEP). Polyvinylidene fluoride (PVDF).

Substance	Perfluorooctanoic acid (PFOA) and similar compounds
Main article groups	PTFE is used as coating of metals, e.g. for non-stick cookware; in seals, gaskets, packings, valve and pump parts and laboratory equipment; in wire and cable insulation, moulded electrical components, insulated transformers, hermetic seals for condensers, and laminates for printed circuitry [Chanda and Roy, 2008]. PVDF is commonly used as e.g. insulation in certain electrical wires (e.g. in computers and in airplanes, and in the chemical industry to make pipes and bottles and such that hold chemicals [Polymer science learning center. 2005].
Potential for release from plastics	The substance is not chemically bound and will migrate. Experiments with heated Teflon® (Du Pont PTFE) frying pans indicate release of perfluorocarboxylic acids (i.e. PFOA) at temperatures of 360 °C (a PTFE-coated pan can reach 400 °C) [Järnberg et al, 2006].
Potential for exposure of consumers	Exposure is likely.
Fate of the substance by recycling	Unknown – Recycling is normally not practised as PTFE typically is used as coating on other materials.
References	Chanda, M., Roy, S.K., (2008). Industrial Polymers, Specialty Polymers and Their Applications. Plastics Engineering Series. CRC Press, Taylor & Francis Group, Boca Raton. Järnberg, U., Holmström, K. van Bavel, B., Kärrman, A. (2006). Perfluoroalkylated acids and related compounds (PFAS) in the Swedish environment. http://www.swedishepa.se/upload/02_tillstandet_i_miljon/Miljoovervakning/rapporter/miljogift/PFAS_ITMreport_06oct.pdf Lithner, D, Larsson, Å. Dave, G. (2011). Supplementary appendix in: Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of the total environment, 409: 3309-3324. Polymer science learning center. (2005). Polyvinylidene fluoride. http://www.pslc.ws/macrog/pvdf.htm Poulsen P.B., Jensen A.A., Wallström E. (2005). More environmentally friendly alternatives to PFOS-compounds and PFOA. Environmental Project No. 1013/2005. The Danish Environmental Protection Agency.

3.11.4 Henicosafluoroundecanoic acid, heptacosafluorotetradecanoic acid, tricosafluorododecanoic acid, pentacosafluorotridecanoic acid, heptadecafluorononanoic acid and nonadecafluorodecanoic acid

Substance	Henicosafluoroundecanoic acid, Heptacosafluorotetradecanoic acid, Tricosafluorododecanoic acid, Pentacosafluorotridecanoic acid, heptadecafluorononanoic acid and nonadecafluorodecanoic acid
CAS Number	2058-94-8, 376-06-7, 307-55-1, 72629-94-8, 375-95-1, 335-76-2
Justification	Candidate list; Registry of intentions (CLP, SVHC)).
Function	No data – assumed to correspond to function for PFOA and similar substances: (Dispersing agent (for production of special plastics e.g. PTFE)).
Relevant types of plastics	No data – assumed to correspond to PFOA and similar substances: (Polytetrafluorethylene (PTFE) and fluoroethylene propylene (FEP). Polyvinylidene fluoride (PVDF)).

Substance	Henicosafluoroundecanoic acid, Heptacosafluorotetradecanoic acid, Tricosafluorododecanoic acid, Pentacosafluorotridecanoic acid, heptadecafluorononanoic acid and nonadecafluorodecanoic acid
Main article groups	No data – assumed to correspond to PFOA and similar substances: (PTFE is used as coating of metals; PVDF is commonly used as e.g. insulation in certain electrical wires).
Potential for release from plastics	CAS no. 2058-94-8: Molecular weight: 564.09 g/mol, boiling point: 238.4 °C at 101.325 kPa (calculated), vapour pressure: 0.6 to 99.97 kPa (112 to 237.7°C) (calculated), adsorption/desorption: log Koc 3.19 – 3.41 [Annex XV dossier - Henicosafluoroundecanoic acid.]. CAS no. 376-06-7: Molecular weight: 714.11 g/mol, boiling point: 270 °C at 98.6 kPa, vapour pressure: 1.37E-3 torr at 25 °C = 0.183 Pa, partition coefficient (log P): 10.823±0.914 at 25 °C (calculated) [Annex XV dossier - Heptacosafluorotetradecanoic acid]. The other substances have similar values. Migration is uncertain, but may based on analogy to Perfluorooctanoic acid (PFOA – see section 3.11.3) be considered possible.
Potential for exposure of consumers	Unknown - but may based on analogy to Perfluorooctanoic acid (PFOA – see section 3.11.3) be considered possible.
Fate of the substance by recycling	Unknown – but may based on analogy to Perfluorooctanoic acid (PFOA – see section 3.11.3) be considered irrelevant since recycling is normally not practised as PTFE typically is used as coating on other materials.
References	Annex XV dossier. Henicosafluoroundecanoic acid. http://echa.europa.eu/documents/10162/13638/SVHC_ACCHECK_AXVREP_pub_218-165-4_Henicosafluoroundecanoic_acid_en.pdf Annex XV dossier. Heptacosafluorotetradecanoic acid. http://echa.europa.eu/documents/10162/bd9c539e-19e0-4f67-a31a-0a6f5e8c9b8d Annex XV dossier. Tricosafluorododecanoic acid. http://echa.europa.eu/documents/10162/84bc1dc7-3898-449f-ba44-c20a56ea5452 Annex XV dossier. Pentacosafluorotridecanoic acid. http://echa.europa.eu/documents/10162/f4be09a8-ff79-48f1-8175-54fb5c7bac90

3.11.5 Polyaromatic Hydrocarbons (PAHs)

Substance	PolyAromatic Hydrocarbons (PAHs)
CAS Number	50-32-8, 56-55-3, 120-12-7, 192-97-2, 193-39-5, 205-82-3, 205-99-2, 207-08-9, 218-01-9, 65996-93-2, 90640-80-5, 90640-81-6, 90640-82-7, 90640-86-1, 91995-15-2, 91995-17-4, etc. PAHs are usually present as a complex mixture of several hundred congeners.
Justification	Norwegian priority list; Registry of intentions (CLP and SVHC).
Function	Impurity in plasticisers (e.g. mineral oil and coal based extender oils) and carbon black [BfR, 2010].
Relevant types of plastics	Soft plasticised plastics, and other plastic types such as acrylonitrile-butadiene-styrene (ABS) and polypropylene (PP) [Central Experience Exchange Committee, 2008]. All plastics coloured black.

Substance	PolyAromatic Hydrocarbons (PAHs)
Main article groups	E.g. tool handles, bicycle handlebars, slippers, flip-flops, beach sandals, diver equipment, toy car tyres or clay pigeons used in skeet shooting. PAHs may also be contained in synthetic turf or in materials used for construction work, e.g. flooring material and plastic handles [BfR, 2010]. Furthermore, all plastic products coloured black might contain PAH.
Potential for release from plastics	Migration and release of PAHs from plastics etc. are discussed by [BrF, 2010]. The conclusion is that for some products significant release and thereby dermal exposure to humans can be expected.
Potential for exposure of consumers	There is a potential for exposure for PAH´s from plastics with added carbon black but the level will be extremely low due to the low mobility and the high tendency to absorption in the carbon black matrix.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the low mobility and the high tendency to absorption in the carbon black matrix.
References	BfR (2010). Carcinogenic polycyclic aromatic hydrocarbons (PAHs) in consumer products to be regulated by the EU - risk assessment by BfR in the context of a restriction proposal under REACH. BfR Opinion Nr. 032/2010, 26 July 2010. The Federal Institute for Risk Assessment. Germany http://www.bfr.bund.de/cm/349/carcinogenic_polycyclic_aromatic_hydrocarbons_pahs_in_consumer_products_to_be_regulated_by_the_eu.pdf Central Experience Exchange Committee (2008). Testing and Validation of Polycyclic Aromatic Hydrocarbons (PAH) in the course of GS-Mark Certification. Not authorized translation of original document. http://www.cnqa.org/upimg/20092167421780.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.11.6 Potassium hydroxyoctaoxodizincatedichromate

Substance	Potassium hydroxyoctaoxodizincatedichromate -see also section 3.5.2
CAS Number	11103-86-9
Justification	Norwegian priority list; Candidate list; Registry of intentions (SVHC).
Function	Corrosion inhibition (in plastic resins for primers, coatings and sealants) to metal substrates (iron, steel, galvanized steel, zinc, aluminium and aluminium alloys)
Relevant types of plastics	Epoxy, polyurethane, alkyd, isocyanate-cured polyester, acrylic resins containing pigments are used as topcoats and primers [Annex XV report].
Main article groups	Coatings in the aeronautic/aerospace sector and the automotive sector (heavy duty vehicles and trucks, military vehicles, agricultural equipment) [Annex XV report].
Potential for release from plastics	Molecular weight: 418.9 g/mol, boiling point: 250 °C (as chromates) [New Jersey – Hazardous Substance Fact Sheet], vapour pressure: data not available, partition coefficient (log value) log P_{ow}: data not available (inorganic compound) [Annex XV report]. The substance is solid bound and will not migrate. Release will only take place by wear and tear and by e.g. sandgrinding of surfaces before maintenance.

Substance	Potassium hydroxyoctaoxodizincatedichromate -see also section 3.5.2
Potential for exposure of consumers	Very low as solid bound.
Fate of the substance by recycling	Unknown – Recycling is normally not practised as the substance typically is used in coatings on other materials.
References	Annex XV report. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_france_cmr_potassium_hydroxyoctaoxodizinccatedichromate_20110829_en.pdf New Jersey 2008. Zinc potassium chromate – Hazardous Substance Fact Sheet. http://nj.gov/health/eoh/rtkweb/documents/fs/2042.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

3.11.7 Disodium tetraborates

Substance	Disodium tetraborate, anhydrous Disodium tetraborate decahydrate Disodium tetraborate pentahydrate
CAS Number	1330-43-4, 1303-96-4, 12179-04-3
Justification	Danish list of undesired substances; Candidate list; Registry of intentions (SVHC); CMR.
Function	Disodium tetraborate decahydrate (1303-96-4) used as buffering agent (in formaldehyde resins). Disodium tetraborate pentahydrate (CAS 12179-04-3) used for production of plastics, resins, nylon. [Annex XV dossier].
Relevant types of plastics	Formaldehyde resins (not further specified) - no further data [Annex XV dossier].
Main article groups	No information.
Potential for release from plastics	CAS no. 12179-04-3: Molecular weight: 291.35 g/mol, melting point/ boiling point: >300 °C [Annex XV dossier], vapour pressure: negligible at 20 °C, partition coefficient (log value) log P_{ow}: -0.757 at 25 °C [20 Mule team, 2008]. Not possible to assess potential for release due to lack of data.
Potential for exposure of consumers	If left in the formaldehyde resins it is judged that exposure might take place due to the high solubility in water expressed by the partition coefficient.
Fate of the substance by recycling	Judged to mainly remain in the plastic by mechanical recycling due to the high melting and boiling point. However the substance might dissolve in the washing processes due to the high solubility in water.

Substance	Disodium tetraborate, anhydrous Disodium tetraborate decahydrate Disodium tetraborate pentahydrate
References	Annex XV dossier. http://echa.europa.eu/documents/10162/13640/svhc_axvrep_denmark_cmr_tetraboron_disodium_en.pdf 20 Mule team (2008). Borax Pentahydrate – Material Safety Data Sheet. http://www.hillbrothers.com/msds/pdf/n/borax-pentahydrate.pdf Nilsson N. (2014). Expert assessment by Nils H. Nilsson, Danish Technological Institute, Århus, April 2014.

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Annex XV dossiers/reports.
For all substances included on the REACH Candidate List an Annex XV dossier/report is available. These reports have all been published by ECHA and are available on the internet. These reports are listed under the relevant substances, but are not included in the following list of references.

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Abbreviations and acronyms

ABS	Acrylonitrile butadiene styrene
ADCA	C,C'-azodi(formamide)
ATBC	Acetyl tributyl citrate
BBP	Benzyl butyl phthalate
BPA	Bisphenol A
CAS	Chemical Abstracts Service
Cd	Cadmium
C.I.	Colour Index
CLP	Classification, labelling and packaging of substances and mixtures (EU regulation)
CMR	Carcinogenic, Mutagenic or toxic to Reproduction
COMGHA	Castor oil derivatives
CP	Chlorinated paraffins
CPE	Chlorinated polyethylene
DBP	Dibutyl phthalate
DEHP	Bis(2-ethylhexyl)phthalate
DEHT	Di(2-ethyl-hexyl)terephthalate
DHNUP	1,2-Benzenedicarboxylic acid, di-C7-11-branched and linear alkyl esters
DIBP	Diisobutyl phthalate
DIHP	Diisoheptylphthalat/diisohexylphthalate
DINA	Diisononyl adipate
DINCH	Di-(isononyl)-cyclohexane-1,2-dicarboxylate
DINP	Diisononyl phthalate
DMEP	Bis(2-methoxyethyl) phthalate
DMF	N,N-dimethylformamide
EC	European Community
ECHA	European Chemicals Agency
EPA	Environmental Protection Agency
EPS	Expanded PolyStyrene
EU	European Union
EVA	Ethylene-vinylacetate copolymers
FEP (a)	Fluoroethylene propylene
FEB (b)	Tetrafluoroethylene-Hexafluoropropylene-Copolymer
HBCDD	Hexabromocyclododecane
HCl	Hydrochloric acid
HDPE	PolyEthylene - High Density
HFC	Hydro fluoro carbon
Hg	Mercury
HIPS	High Impact PolyStyrene
hPa	Hectopascal
KLIF	The Norwegian Environmental Protection Agency
LDPE	PolyEthylene - Low Density
LLDPE	PolyEthylene - Linear Low Density
Log $K_{o/w}$	Corresponds to log $P_{o/w}$

Log $P_{o/w}$	Partition-coefficient (octanol/water)
LOUS	List of undesired substances
MCCP	Medium-chain chlorinated paraffins
MDA	4,4'- Diaminodiphenylmethane
MDI	Methylene diphenyldiisocyanate
MOCA	2,2'-dichloro-4,4'-methylenedianiline
MSDS	Material safety data sheet
MW	Molecular weight
NGO	Non governmental organisation
NIR	Near-infrared spectroscopy
NP	Nonylphenol
OBPA	10,10'-oxybisphenoxarsine
OBDE	Octabromodiphenyl ether
OP	Octylphenol
OPET	A special type of PET (oriented PET)
PA	Polyamides (nylon)
PA66	Special type of polyamide
Pa	Pascal
PAH	Polyaromatic hydrocarbons
PBT	Polybutylene terephthalate
PBT	Persistent, bioaccumulative and toxic
PC	Polycarbonate
PE	Polyethylene
PEEK	Polyetheretherketone
PeBDE	Pentabromodiphenyl ether
PET	Polyethylene terephthalate (polyester)
PFOA	Perfluorooctanoic acid
pH	A measure of the acidity or basicity of an aqueous solution
PIB	Polyisobutylene plastic
PMMA	Polymethyl methacrylate
POM	Polyoxymethylene
POP	Persistant organic pollutants
PP	Polypropylene
PPE	Polyphenylen ether
PPE-HIPS	Blend of polyphenylene ether and high impact polystyrene
PS	Polystyrene
PSU	Polysulphone
PTFE	Polytetrafluoroethylene (teflon)
PU	Polyurethane
PUR	Polyurethane
PVA	Polyvinylacetate
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
REACH	REACH is the European Community Regulation on chemicals and their safe use. It deals with the **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances
RoHS	Restriction of Hazardous Substances (EU regulation)
SAN	Styrene Acrylonitrile
SCCP	Short Chain Chlorinated Paraffins
SDS	Safety data sheet
SIAR	OECD SIDS Initial Assessment Report
SIDS	OECDs Screening Information Dataset
SVHC	Substances of Very High Concern

TBBPA	Tetrabromobisphenol A
TBTO	Bis(tributyltin)oxide
TCEP	Tris(2-chloroethyl)phosphate
TGIC	1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione
β-IC	1,3,5-Tris[(2S and 2R)-2,3-epoxypropyl]-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione
TDI	Toluene-diisocyanate
Tm	Melting temperature of plastics containing crystalline domains
TNPP	Tris(4-nonyl-phenyl) phosphate
Torr	A unit of pressure equal to 1/760 atmosphere (about 133.3 pascals or 1 mm Hg)
TPU	Thermoplastic polyurethane
UP	Unsaturated polyesters
US EPA	United States Environmental Protection Agency
UV	Ultraviolet (light)
UV/VIS	Ultraviolet/visible
XPS	Extruded PolyStyrene
X-rays	Form of electromagnetic radiation.
VCR	Video casette recorders
vPvB	Very persistent and very bioaccumulative
w/w	By weight

Annex 1 Listed substances not likely to be used in plastics

In this annex the substances not likely to be present in significant concentrations or more than trace levels in the final plastic products are presented.

The substances presented belong to the following lists:

- The Danish list of undesired substances;
- The updated SVHC (substances of Very High Concern) candidate list under REACH;
- Norwegian Priority List of hazardous substances;
- ECHA's Registry of Intentions;
- A List of CMR-substances in toy likely to be present in plastic toys prepared by Danish Technological Institute;
- Recognized alternatives to problematic phthalates and brominated flame retardants.

First, substances belonging to the Danish list of undesired substances are presented, followed by the substances on the EU Candidate list (June 2013), then substances or substance groups on the Norwegian priority list etc.

For most of the substances there is not a complete coverage in the available literature of all uses for a substance, and in some cases the information is very scarce. It is, therefore, often not possible to conclude with certainty that the substance is not in any way used in plastics. The list could, therefore, include substances which in some minor applications are used in plastics.

The method for screening the substances and the main sources of information are described in chapter 2.

Substance	CAS No.	Use associated with plastic
Danish list of undesired substances		
Benzyl chloride	100-44-7	Intermediate for plasticisers - present as an impurity in BBP (< 2ppm) [Annex XV report – BBP]
Biphenyl	92-52-4	Intermediate for e.g. plastics - assessed as non-important
Bisphenol A diglycidyl ether polymer	25036-25-3	Polymer/plastic material based on bisphenol A
Boric compounds (classified) Sodium perborate tetrahydrate Diboron trioxide	 10486-00-7 1303-86-2	 Not used in plastics May be use used in dyes for synthetic textiles [Annex XV], but no detailed information has been found
2,3-epoxypropyl neodecanoate	26761-45-5	Little information available - no indication of use in plastics
n-hexane	110-54-3	Solvent – not used in plastics
2,2'-Iminodiethanol	111-42-2	Not used in plastics
Copper(I) oxide Copper(II) sulphate Copper(I) chloride	1317-39-1 7758-98-7 7758-89-6	Copper(I)chloride is used as intermediate in manufacturing of pigments - indications that copper(I)oxide and copper(II)sulphate may be used in rubbers and plastics, but no further information is available [Hansen et al 2013] Potential occurrence in plastics is thus assessed as insignificant
Manganese(II) sulphate	7785-87-7	Not used in plastics
Methanol	67-56-1	Not used in plastics
MTBE methyl-tertiary butyl ether	1634-04-4	Not used in plastics
1-Methyl-2-pyrrolidone (NMP)	872-50-4	Spinning agent (for PVC); binder in waterborne PU topcoat, solvent [Annex XV]
Napthalene	91-20-3 202-049-5	Intermediate used in the production of plastics - potential occurrence in plastics is assessed as insignificant
Sodium hypochlorite Calcium hypochlorite	231-668-3 231-908-7	Disinfectant, cleaning agent – not used in plastic
Nickel (metal)	7440-02-0	Not used in plastics
Certain oil and coal derivatives Mineral turpentine Solvent naphta (petroleum), medium aliphatic	 8052-41-3 64742-88-7	Not used in plastics
Organic solvents Toluene	 108-88-3	 Toluene is used as intermediate in production of TDI and is likely not relevant to consider
Certain parabens (propyl and butyl paraben) Propyl paraben Butyl paraben	 94-13-3 94-26-8	Used in cosmetics etc. but not in plastics.

Perfume ingredients		Used in cosmetics etc. but not in plastics.
PFOS (Perfluorooctanesulfonic acid or perfluorooctane sulfonate)	e.g. 4151-50-2	Used in firefighting foams, photographic industry, photolithography and semiconductors, hydraulic fluids and in metal plating industry2 [UNECE, 2006] - in the past used to provide soil, oil and water resistance to textiles, apparels, home furnishings and upholstery, carpets and leather products [UNECE, 2006]
N´-tert-butyl-N-cyclopropyl-6-(methylthio)-1,3,5-triazine-2,4-diamine	28159-98-0	Not used in plastics
Trisodium nitrilotriacetate	5064-31-3	Not used in plastics
Substances on the EU CANDIDATE LIST		
Acids generated from chromium trioxide and their oligomers. Names of the acids and their oligomers: Chromic acid, Dichromic acid, Oligomers of chromic acid and dichromic acid.	7738-94-5, 13530-68-2	Used with sulfuric acid as an etchant for plastics such as ABS, modified polypropylene, polysulfone [Milne, 2005, Muccio, 1991]
Aluminosilicate Refractory Ceramic Fibres		Not used in plastics [Annex XV]
[4-[[4-anilino-1-naphthyl][4-(dimethylamino)phenyl]methylene]cyclohexa-2,5-dien-1-ylidene] dimethylammonium chloride (C.I. Basic Blue 26) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	2580-56-5	Dyeing of various paper and plastic products [Annex XV]
Anthracene	120-12-7	Doping agent for polyvinyltoluene to produce a plastic scintillator. [Several internet sources, 2012] - to the best of knowledge not used in plastic
Anthracene oil	90640-80-5	Mainly intermediate in the production of pure anthracene used for production of artificial dyes - not used in plastics [Annex XV]
Anthracene oil, anthracene paste	90640-81-6	Same as antracene oil (above) - not used in plastics
Anthracene oil, anthracene paste, anthracene fraction	91995-1-2	Same as antracene oil (above) - not used in plastics
Anthracene oil, anthracene paste,distn. lights	91995-17-4	Same as antracene oil (above) - not used in plastics
Anthracene oil, anthracene-low	90640-82-7	Same as antracene oil (above) - not used in plastics

[4-[4,4'-bis(dimethylamino) benzhydrylidene]cyclohexa-2,5-dien-1-ylidene]dimethylammonium chloride (C.I. Basic Violet 3) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	548-62-9	A component of navy blue and black dyes for polyacylonitrile fibers [Annex XV]
4,4'-bis(dimethylamino) benzophenone (Michler's ketone)	90-94-8	Intermediate in the manufacture of triphenylmethane dyes [Annex XV] - not used in plastics
4,4'-bis(dimethylamino)-4''-(methylamino)trityl alcohol [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	561-41-1	Used in inks and dyes [ECHA 2013] - may be used in dyes for polyacrylonitrile materials [Annex XV]
Bis(2-methoxyethyl) ether	111-96-6	Used as a solvent for PVC/PVA copolymer and polymethyl methacrylate [Milne, 2005] Used for purification and solvent in production of magnetic polystyrene beads [Annex XV]
α,α-Bis[4-(dimethylamino)phenyl]-4(phenylamino)naphthalene-1-methanol (C.I. Solvent Blue 4) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	6786-83-0	Is used for dying of plastics [Annex XV]
1,2-bis(2-methoxyethoxy)ethane (TEGDME; triglyme)	112-49-2	Substance in etchant formulation [Annex XV] used to make fluoropolymers bondable to a wide variety of articles - there is only limited information on the current use of the substance [Annex XV]
Cobalt(II) carbonate	513-79-1	Catalyst in the production of p-xylene to terephthalic acid (which is a monomer for PET) [Annex XV]
Cobalt dichloride	7646-79-9	Intermediate for other cobalt compounds, electroplating, pigments and dyes - no information of use in plastics [Annex XV; Entec, year unknown; Krebs, 2006; Environment Canada, 2011]
Cobalt(II) dinitrate	10141-05-6	Used mainly in the manufacture of catalysts and production of intermediate chemicals - not used in plastics [Annex XV]
Cobalt(II) sulphate	10124-43-3	Used in organic textile dyes (cobalt complexes of azo-dye derivates), which could be used in synthetic textiles [Annex XV]
Diboron trioxide	1303-86-2	May be use used in dyes for synthetic textiles [Annex XV], but no detailed information has been found
1,2-Dichloroethane	107-06-2	Precursor in the production of vinyl chloride monomer

		for the production of PVC, (an alternative route exists) [Annex XV] Will easily evaporate - will to the best of knowledge not be present in plastic end products
Dichromium tris(chromate)	24613-89-6	Surface treatment of metals - not used in plastics [Annex XV]
1,2-dimethoxyethane; ethylene glycol dimethyl ether (EGDME)	110-71-4	Processing aid for Fluor polymer Etchant formulation, which is used to make fluoropolymers bondable to a wide variety of articles, i.e., Teflon [Annex XV]
N,N-dimethylacetamide (DMAC)	127-19-5	Spinning of textile fibres [Annex XV]
2,4-Dinitrotoluene	121-14-2	Used to make tolulenediamine which is an intermediate for tolulenediisocyanate [OECD, 2004], the intermediate for TDI which is used for making flexible polyurethane foam
2-Ethoxyethanol	110-80-5	Solvent for nitrocellulose, epoxy coatings, alkyd resins [Ash and Ash, 2007]
2-Ethoxyethyl acetate	111-15-9	It is reported in the sector of rubber and plastic industry [Annex XV], but no other information to confirm this has been found *Note:* To the best of knowledge it is not used to any significant extent in plastics
Formamide	75-12-7	Solvent (for synthetic leather)*, by-product in the processing of foam (EVA) [Annex XV] - solvent for polymers such as PVC and polyacrylonitrile [Swedish Chemicals Agency, 2010] * Besides in the Annex XV report there is no information that formamide is used in the production of synthetic leather
2-Methoxyaniline o-Anisidine	90-04-0	Component of azo and naphtol pigments and dyes used in dyed and printed polymers especially in printed packing foils [Annex XV]
1-Methyl-2-pyrrolidone (NMP)	872-50-4	Spinning agent (for PVC); binder in waterborne PU topcoat, solvent [Annex XV]
Pentazinc chromate octahydroxide	49663-84-5	Used as anti-corrosive agent in primers, and colouring, hiding and anti-scaling agent in paints and coatings - not used in plastics [Annex XV]
Phenolphthalein	77-09-8	Laboratory uses etc. - not used in plastics [Annex XV]
5-tert-butyl-2,4,6-trinitro-m-xylene (musk xylene)	81-15-2	Used in fragrance formulation in household and cosmetic products - not used in plastics [EU, ≥2008]

Tetraboron disodium heptaoxide, hydrate	12267-73-1	Used in glass, ceramics, detergents, wood treatment, insulation fiberglass and various unspecified uses such as production of other borate compounds [Annex XV] - to the best of knowledge not used to any significant extent in plastics
N,N,N',N'-tetramethyl-4,4'-methylenedianiline (Michler's base)	101-61-1	Intermediate in the manufacture of dyes and pigments (including Methylene red, C.I. Basic Yellow 2, Basic Orange 14, Solvent Orange 15, and Solvent Yellow 34 and C.I. Basic Violet 3 [Annex XV]) Information on whether these pigments are used in plastics/fibres has not been found
Zirconia Aluminosilicate Refractory Ceramic Fibres…		High-temperature insulating fibre for industrial applications - not used in plastics [Annex XV]
Dipentyl phthalate (DPP)	131-18-0	May be used as plasticiser in PVC - not manufactured in EU - consumption in EU assessed as <1 tons per year [Annex XV dossier – DPP]
6-methoxy-m-toluidine (p-cresidine)	120-71-8	Intermediate, manufacture of pigments [ECHA 2013] - no other information available
4-Aminoazobenzene	60-09-3	Intermediate, manufacturing of pigment – no other information available [ECHA 2013]
o-Toluidine	95-53-4	Intermediate – no other information available [ECHA 2013]
3-ethyl-2-methyl-2-(3-methylbutyl)-1,3-oxazolidine	143860-04-2	No information available [ECHA 2013] Manufacture of substances – stated by MSDS
4,4'-methylenedi-o-toluidine	838-88-0	No information available [ECHA 2013] Manufacture of substances – stated by MSD
Diethyl sulphate	64-67-5	Intermediate - reactant in the synthesis of polymers - no other information available [ECHA 2013]
Dimethyl sulphate	77-78-1	Intermediate - synthesis of polymers - no other information available [ECHA 2013]
Furan	110-00-9	Intermediate – no other information available [ECHA 2013]
Dinoseb (6-sec-butyl-2,4-dinitrophenol)	88-85-7	Intermediate - manufacture of plastics products, including compounding and conversion - no other information available [ECHA 2013]
1,2-Diethoxyethane	629-14-1	Solvents for some resins – no other indications of use related to plastics are presented [Annex XV – Diethoxyethane]
N-methylacetamide	79-16-3	Intermediate – no other information available [ECHA 2013]
N-pentyl-isopentylphthalate	776297-69-9	May be used as plasticiser in plastic materials - not manufactured in EU - consumption in EU assessed as <1 tons per year [Annex XV dossier – PIPP]
1-bromopropane (n-propyl bromide)	106-94-5	Intermediate – manufacture of solvent for cleaning/degreasing - end use includes manufacture of plastics products, including compounding and conversion No other information available [ECHA 2013] According to MSDS use is as a solvent, generally for fats,

		waxes, or resins, or as an intermediate in the synthesis of other compounds Assessed as unimportant related to plastics
Methoxyacetic acid	625-45-6	No information indicates the substance to be used in plastics or in manufacture of plastics [Annex XV dossier – Methoxyacetic acid]
o-aminoazotoluene	97-56-3	Intermediate in the manufacture of dyes and medicines [NCBI – Aminoazotoluene] - no other information available [ECHA 2013]
4-methyl-m-phenylenediamine (toluene-2,4-diamine)	95-80-7	Intermediate - production of sulphur dyes [ECHA]
1,2-Benzenedicarboxylic acid, dipentylester, branched and linear	84777-06-0	May be used as plasticiser in plastic materials - not manufactured in EU - consumption in EU assessed as <1 tons per year [Annex XV dossier - benzenedicarboxylic acid, dipentylester]
Biphenyl-4-ylamine	92-67-1	Intermediate (according to MSDS) – no other information available - substance is not registered [ECHA 2013]
4,4'-oxydianiline and its salts	101-80-4	Intermediate - the substance is a monomer within an imported polymer [ECHA 2013] - no other information available - assessed not to be present in significant concentrations in plastic end products.
Substances on the NORWEGIAN PRIORITY LIST		
1,2-Dichloroethane	107-06-2	Precursor in the production of vinyl chloride monomer for the production of PVC, (an alternative route exists) [Annex XV] Will easily evaporate - will to the best of knowledge not be present in the plastic material
Certain surfactants (DHTDMAC, DSDMAC, DTDMAC)		Used as fabric softeners etc. [Knepper et al, 2003; OECD, 1996; EU, 2009] According to one article by McLauchlin et al, [2011] DTDMAC can be used to modify clay mineral (giving a dual surfactant organoclay), which can be used (in amounts of 4 %) in the production of poly(butylene terephthalate (PBT) nanocomposites [McLauchlin et al, 2011] This has not been confirmed by other sources
Dioxins and furans		Dioxins may form during combustion of chlorinated material, e.g. PVC [UNEP, 1999]
Chlorinated alkylbenzenes	e.g. 85117-42-6	Almost no information is available - information available on the internet indicates that chlorinated alkylbenzenes may be used as chemical intermediates for the preparation of monomers and plasticisers etc. - they may also be as result of degradation or combustion processes
Hexachlorobenzene	118-74-1	HCB is no longer directly used - it was e.g. commonly

		used as a pesticide until 1965 [US EPA, 2011]
Muskxylenes	e.g. 81-15-2	Used in fragrance formulation in household and cosmetic products - not used in plastics [EU, ≥2008]
Pentachlorophenol		Biocide in textiles Can be used in thermoplastic polyester in roughly estimated amounts of (0.1-1 %) [Swedish Chemicals Agency, 2007]
PFOS (Perfluorooctanesulfonic acid or perfluorooctane sulfonate)		Used in firefighting foams, photographic industry, photolithography and semiconductors, hydraulic fluids and in metal plating industry2 [UNECE, 2006] - in the past used to provide soil, oil and water resistance to textiles, apparels, home furnishings and upholstery, carpets and leather products [UNECE, 2006]
Polychlorinated biphenyls (PCBs)		Previously used as plasticisers and polyolefin catalysts [Breivik, 2005] According the Swedish Chemicals Agency's guide on articles PBC can be used in thermoplastic polyester in roughly estimated amounts of (0.1-1 %) [Swedish Chemicals Agency, 2007] - no other information has been found to confirm this
Siloxane-D5 Decamethylcyclopentasiloxan (D5)	541-02-6	Mainly used in blending and formulating personal-care products and cosmetics [Fishlock, 2012; Environment Canada, 2012] - intermediate in the production of polydimethylsiloxane silicone polymers [Fishlock, 2011] Examples of uses in plastics have not been found
Tetrachloroethene (PER)	127-18-4	Major use as chemical intermediate, dry cleaning solvent, metal cleaning and extraction processes - used to remove lubricants in knitted or weaved synthetic fabrics [EU, 2005]
Trichlorobenzene	120-82-1	Solvent and intermediate for pesticides - as a dye carrier (mixed with a levelling agent) applied mainly to polyester materials [EU, 2003]
2,4,6 Tri-tert-butylphenol	732-26-3	Maybe used as an intermediate in the production of antioxidants for plastics [Environment Canada 2008] According the Swedish Chemicals Agency [2007] it can be used in thermoplastic polyester in roughly estimated amounts of (0.1-1 %)
ECHA's registry of intentions		
Carbetamide (ISO); (2R)-1-(ethylamino)-1-oxopropan-2-yl phenylcarbamate	16118-49-3	Intermediate – no indication of association with plastics
2-Benzyl-4-chlorophenol	120-32-1	Intermediate – no indication of association with plastics

Fenpyrazamine	473798-59-3	No information
Pirimicarb (ISO); 5,6-dimethyl-2-dimethylamino-pyrimidin-4-yl N,N-dimethylcarbamate	23103-98-2	Insecticide [Pesticides 2103]- no indication of association with plastics
Clethodim (ISO); 2-[N-{[(2E)-3-chloroprop-2-en-1-yl]oxy}propanimidoyl]-5-[2-(ethylthio)propyl]-3-hydroxycyclohex-2-en-1-one	99129-21-2	Herbicide[Pesticides 2013] - no indication of association with plastics
Quinolin-8-ol	148-24-3	Intermediate, steel electroplating, formerly fungicide - no indication of association with plastics
1,2-dichloropropane; propylene dichloride	78-87-5	Intermediate, solvent, thinner, degreasing etc. - no indication of association with plastics [ECHA 2013]
Reaction mass of: 2-(2H-benzotriazol-2-yl)-4-methyl-5-dodecyl (linear and branched) phenol; 2-(2H-benzotriazol-2-yl)-4-methyl-6-dodecyl (linear and branched) phenol; 2-(2H-benzotriazol-2-yl)-4-methyl-5-tetracosyl (linear and branched) phenol; 2-(2H-benzotriazol-2-yl)-4-methyl-6-tetracosyl (linear and branched) phenol; 2-(2H-benzotriazol-2-yl)-4-methyl-5,6-didodecyl (linear and branched) phenol		The substance is not well identified and the meaning of the term "reaction mass of" is unclear - the substances are thus not included The substance could be a UV-stabilizer
5-Chloro-2-(4-chlorophenoxy)-phenol	3380-30-1	Disinfectant - no indication of association with plastics
N,N-dimethylacetamide (DMAC)	127-19-5	Spinning of textile fibres [Annex XV]
Chloralose (INN); (R)-1,2-O-(2,2,2-trichloroethylidene)-Î±-D-glucofuranose; glucochloralose; anhydroglucochloral	15879-93-3	Avicides, bird repellents, rodenticides [Pesticides 2013]- no indication of association with plastics
Chlorobenzene	108-90-7	Intermediate, heat transfer fluid - no indication of association with plastics [ECHA 2013]
TBHP (Hydroperoxide, 1,1-Dimethylethyl)	75-91-2	Intermediate, process regulators for polymerisation processes in production of resins, rubbers, polymers [ECHA 2013] - free radical initiator for polymerizations, copolymerization, graft polymerizations and curing of polymers [Lyondell 2013] - assumed not to be present in end plastic products
Bendiocarb (ISO); (2,2-dimethyl-1,3-benzodioxol-4-yl N-methylcarbamate)	22781-23-3	Insecticide [Pesticides 2013] - no indication of association with plastics
Thiacloprid (ISO); (Z)-N-{3-[(6-Chloro-3-pyridinyl)methyl]-1,3-thiazolan-2-yliden}cyanamide	111988-49-9	Insecticide [Pesticides 2013] - no indication of association with plastics
1-Methyl-2-pyrrolidone (NMP)	872-50-4	Spinning agent (for PVC); binder in waterborne PU topcoat, solvent [Annex XV]
Triflumizole ((E)-4-chloro-Î±,Î±,Î±-trifluoro-N-(1-imidazol-1-yl-2-)	99387-89-0	Fungicide[Pesticides 2013] - no indication of association with plastics
Flumioxazin (ISO); N-(7-fluoro-3,4-dihydro-3-	103361-09-7	Herbicide[Pesticides 2013] - no indication of association

oxo-4-prop-2-ynyl-2H-1,4-benzoxazin-6-yl)cyclohex-1-ene-1,2-dicarboxamide		with plastics
Polyhexamethylene biguanide hydrochloride (PHMB)	27083-27-8 or 32289-58-0	Biocide, disinfectant - no indication of association with plastics
Pencycuron (ISO); 1-(4-chlorobenzyl)-1-cyclopentyl-3-phenylurea	66063-05-6	Fungicide [Pesticides 2013]- no indication of association with plastics
Hydroxyisohexyl 3-cyclohexene carboxaldehyde (INCI); reaction mass of 4-(4-hydroxy-4-methylpentyl)cyclohex-3-ene-1-carbaldehyde and 3-(4- hydroxy-4-methylpentyl)cyclohex-3-ene-1- carbaldehyde [1]; 4-(4-hydroxy-4-methylpentyl)cyclohex-3-ene-1-carbaldehyde [2]; 3-(4-hydroxy-4-methylpentyl)cyclohex-3-ene-1-carbaldehyde [3]	-[1];</br> 31906-04-4 [2];</br> 51414-25-6 [3]	Fragrance ingredients - no indication of association with plastics
Phenol, dodecyl-, branched [Tetrapropenylphenol (TPP)]	121158-58-5	Intermediate, monomer for manufacture of thermoplastics [ECHA 2013] - member of alkylphenol family - According to Lassen et al [2013) 99% of the consumption in EU was used in the production of oil and lubricant additives while small amount was used to produce phenol/formaldehyde resins for printing inks and rubber tyre manufacturing
Sulfoxaflor (ISO); [methyl(oxo){1-[6-(trifluoromethyl)-3-pyridyl]ethyl}-Î»6-sulfanylidene]cyanamide	946578-00-3	Insecticide [Pesticides 2013] - no indication of association with plastics
Linalool	78-70-6	Intermediate – cleaning, cosmetics etc. - no indication of association with plastics [ECHA 2013]
2-(4-tertbutylbenzyl)propionaldehyde	80-54-6	Intermediate – cleaning, cosmetics etc.- no indication of association with plastics [ECHA 2013]
Zinc phosphide; trizinc diphosphide	1314-84-7	Rodenticide [Pesticides 2013] - no indication of association with plastics
Acetochlor(2-chloro-N-ethoxymethyl-6Â´-ethylacet-o-toluidide)	34256-82-1	Herbicide[Pesticides 2013] - no indication of association with plastics
Tinuvin 123; Reaction mass of bis(2,2,6,6-tetramethyl-1-octyloxypiperidin-4-yl)-1,10-decanedioate and 1,8-bis[(2,2,6,6-tetramethyl-4-((2,2,6,6-tetramethyl-1-octyloxypiperidin-4-yl)-decan-1,10-dioyl)piperidin-1-yl)oxy]octane	129757-67-1	Light stabilizer/ UV-absorber - outdoor use (professional) of HALS resulting in inclusion into a matrix, including application in coatings, adhesives and plastics [ECHA 2013] - according to [BASF 2014] only used in coatings (HALS: hindered amine light stabilizers)
Methanol	67-56-1	Not used in plastics
Bupirimate (5-butyl-2-ethylamino-6-methylpyrimidine-4-yl)	41483-43-6	Fungicide [Pesticides 2013] - no indication of association with plastics
Glutaral; glutaraldehyde; 1,5-pentanedial	111-30-8	Disinfectant - no indication of association with plastics
Fluopyram (ISO); N-{2-[3-chloro-5-(trifluoromethyl)pyridin-2-yl]ethyl}-2-(trifluoromethyl)benzamide	658066-35-4	Fungicide [Pesticides 2013]- no indication of association with plastics

Spiroxamine	118134-30-8	Fungicide [Pesticides 2013]- no indication of association with plastics
Bifenazate (ISO); isopropyl 2-(4-methoxybiphenyl-3-yl)hydrazinecarboxylate	149877-41-8	Acaricide [Pesticide 2013] - no indication of association with plastics
Phenol, dodecyl-, branched [Tetrapropenylphenol (TPP)]	121158-58-5	Intermediate, monomer for manufacture of thermoplastics [ECHA 2013] - Member of alkylphenol family - According to Lassen et al [2013) 99% of the consumption in EU was used in the production of oil and lubricant additives while small amount was used to produce phenol/formaldehyde resins for printing inks and rubber tyre manufacturing
Iodomethane	74-88-4	Fungicide, herbicide, insecticide, nematicide [Pesticides 2013] - no indication of association with plastics
Pyridaben (2-tert-butyl-5-(4-tert-butylbenzylthio)-4-chloropyridazin-3(2H)-one)	96489-71-3	Acaricide, insecticide [Pesticides 2013]- no indication of association with plastics
Geranonitril (3,7-dimethylocta-2,6-dienenitrile)	5146-66-7	Syntetic flavour -candles and soap products - no indication of association with plastics
Lenacil (ISO); 3-cyclohexyl-6,7-dihydro-1H-cyclopenta[d]pyrimidine-2,4(3H,5H)-dione	2164-08-01	Herbicide [Pesticides 2013] - no indication of association with plastics
Nitric acid	7697-37-2	Not used in plastics
Lithium sodium 3-amino-10-{4-(10-amino-6,13-dichloro-4,11-disulfonatobenzo[5,6][1,4]oxazino[2,3-b]phenoxazine-3-ylamino)-6-[methyl(2-sulfonato-ethyl)amino]-1,3,5-triazin-2-ylamino}-6,13-dichlorobenzo[5,6][1,4]oxazino[2,3-b]phenoxazine-4,11-disulfonate; Direct Blue FC 57087	154212-58-5	Dye for textiles, leather, fur etc. [CLH Report –Direct blue]
Fluquinconazole (3-(2,4-dichlorophenyl)-6-fluoro-2-(1H-1,2,4-triazol-1-yl)quinazolin-4(3H)-one)	136426-54-5	Fungicide [Pesticides 2013]- no indication of association with plastics
8:2 Fluorotelomer alcohol (8:2 FTOH)	678-39-7	8:2 FTOH is mainly used for coating of textiles, paper and carpets to achieve oil, stain and water repellent properties, cleaning agents and is present as residual raw materials (Dinglasan-Panlilio and Mabury, 2006) - the reaction of fluorotelomer alcohol to make fluorotelomer acrylates or methacrylate esters leaves 0.1-0.5 wt% unreacted residual FTOH [CLH report – 8:2 FTOH]
Special purpose E-glass fibres [Calcium-aluminium-silicate fibres with random orientation with the following composition (% given by weight): SiO2 50.0-56.0%, Al2O3 13.0-16.0%, B2O3 5.8-10.0%, Na2O <0.6%, K2O <0.4%, CaO 15.0-24.0%, MgO <5.5%, Fe2O3 <0.5%, F2 <1.0% with note R. Process: drawing or spinning the molten mix (at approx. 1500Â°C) from nozzles]		No indication of association with plastics

Special purpose 475-glass fibres [Calcium-aluminium-silicate fibres with random orientation with the following composition (% given by weight): SiO2 55.0-60.0%, Al2O3 4.0-7.0%, B2O3 8.0-11.0%, Na2O 9.5-13.5%, K2O 1.0-4.0%, CaO 1.0-5.0%, MgO 0.0-2.0%, Fe2O3 <0.2%, ZnO 2.0-5.0%, BaO 3.0-6.0%, F2 <1.0% with note R. Process: drawing or spinning the molten mix (at approx. 1500Â°C) from nozzles]		No indication of association with plastics
Propamocarb (Propyl 3-(dimethylamino) propylcarbamate hydrochloride)	25606-41-1	Fungicide [Pesticides 2013]- no indication of association with plastics
Picoxystrobin (Methyl (E)-3-methoxy-2-{2-[6-(trifluoromethyl) -2- pyridyloxymethyl]phenyl} acrylate)	117428-22-5	Fungicide [Pesticides 2013] - no indication of association with plastics
Etridiazole	2593-15-9	Fungicide [Pesticides 2013] - no indication of association with plastics
Dodemorph	1593-77-7	Fungicide [Pesticides 2013]- no indication of association with plastics
Dodemorph acetate	31717-87-0	Fungicide [Pesticides 2013]- no indication of association with plastics
Zineb (Carbamaodithioic acid, 1,2-ethane)	12122-67-7	Fungicide [Pesticides 2013]- no indication of association with plastics
Silthiofam (4,5-Dimethyl-2-trimethylsilanyl-thiophene-3-carboxylic acid allylamide)	175217-20-6	Fungicide [Pesticides 2013]- no indication of association with plastics
Diphenylamine	122-39-4	Intermediate - chemical reaction of Diphenylamine with sulphur gives phenothiazine used as stabiliser for plastics. [RAR – diphenylamine 2008] - assessed not to be present in significant concentrations in plastic end products
Isoxaflutole	141112-29-0	Herbicide [Pesticides 2013]- no indication of association with plastics
Tebuconazole	107534-96-3	Fungicide [Pesticides 2013]- no indication of association with plastics
Disodium octaborate, anhydrate	12008-41-2	Intermediate
Disodium octaborate, tetrahydrate	12280-03-4	Biocide - wood preservative
Carvone; 5-isopropenyl-2-methylcyclohex- 2-en-1-one; d/l mixture; [1] d-carvone; [2] l-carvone; [3]	99-49-0 [1] 2244-16-8 [2] 6485-40-1 [3]	Fungicide [Pesticides 2013]- no indication of association with plastics
Coumatetralyl (ISO); 4-hydroxy-3-(1,2,3,4-tetrahydro-1- naphthyl)coumarin	5836-29-3	Rodenticide [Pesticides 2013]- no indication of association with plastics
Fyrolflex	5945-33-5	Phosphorous flame retardant for e.g. polyphenylene PC, ABS, PE, PP, HIPS etc. – for automotive and electronic purposes
(Z,E)-7,11-hexadecadien-1-yl acetate	51606-94-4	Pesticide?
(Z)-11-hexadecen-1-yl acetate	34010-21-4	Pesticide?

(Z)-13-octadecenal	58594-45-9	Pesticide?
(Z)-9-dodecen-1-yl acetate	16974-11-1	Pesticide?
E-5-decen-1-ol	56578-18-8	Pesticide?
(E)-5-decen-1-yl acetate	38421-90-8	Pesticide?
(E,Z)-7,9-dodecadien-1-yl acetate	54364-62-4	Pesticide?
(Z)-11-tetradecen-1-yl acetate	20711-10-8	Pesticide?
(Z,E)-9,12-tetradecadien-1-yl acetate	30507-70-1	Pesticide?
(Z,Z)-7,11-hexadecadien-1-yl acetate	52207-99-5	Pesticide?
(Z)-11-hexadecenal	53939-28-9	Pesticide?
(Z)-8-dodecen-1-yl acetate	28079-04-1	Pesticide?
1-tetradecanol	112-72-1	Monomers for manufacture of thermoplastics [ECHA 2013] - assessed as unimportant due to the chemical structure
(E)-8-dodecen-1-yl acetate	38363-29-0	Pesticide?
E/Z-8-dodecenyl acetate	38363-29-0 / 28079-04-1	Pesticide?
(E)-11-tetradecen-1-yl acetate	33189-72-9	Pesticide?
(E,E)-7,9-dodecadien-1-yl acetate	54364-63-5	Pesticide?
(Z)-7-tetradecenal	65128-96-3	Pesticide?
(Z)-9-tetradecen-1-yl acetate	16725-53-4	Pesticide?
Dodecan-1-yl acetate	112-66-3	Intermediate – no other information available
(E,Z)-2,13-octadecadien-1-yl acetate	86252-65-5	Pesticide?
(Z)-9-hexadecenal	56219-04-6	Pesticide?
Flonicamid	158062-67-0	Insecticide [Pesticides 2013]- no indication of association with plastics
Metosulam	139528-85-1	Herbicide [Pesticides 2013]- no indication of association with plastics
Triflusulfuron (ISO); 2-[4-dimethylamino-6-(2,2,2-trifluoroethoxy)-1,3,5-triazin-2-ylcarbamoylsulfamoyl]-m-toluic acid	126535-15-7	Herbicide [Pesticides 2013]- no indication of association with plastics
(Z)-8-dodecenol	40642-40-8	Pesticide?
Thixatrol Max	-	Used for paints, varnishes, and coatings [ECHA – Thixatrol 2012]
(E,E)-8,10-dodecadien-1-ol	33956-49-9	Pesticide?
Tralkoxydim	87820-88-0	Herbicide [Pesticides 2013]- no indication of association with plastics
(Z)-11-hexadecen-1-ol	56683-54-6	Moth control substance
Copper (I) oxide	1317-39-1	Not included – see Danish list of undesired substances
Copper sulphate pentahydrate	7758-98-7 (7758-99-8 and 12527-76-3)	Not included – see Danish list of undesired substances
Copper (II) hydroxide	20427-59-2	Not used in plastics
Tribasic copper Sulphate	12527-76-3	Not used in plastics
Bordeaux mixture	8011-63-0	Fungicide [Pesticides 2013]- no indication of association with plastics

Copper powder	7440-50-8	Not used in plastics
Proquinazid	189278-12-4	Fungicide [Pesticides 2013]- no indication of association with plastics
Copper Oxychloride	1332-40-7 or 1332-65-6	Not used in plastics
Dimethenamid-P	163515-14-8	Herbicide [Pesticides 2013]- no indication of association with plastics
Basic copper carbonate	12069-69-1	Not used in plastics
Copper (II) oxide	1317-38-0	Not used in plastics
Copper thiocyanate	1111-67-7	Not used in plastics
Tricalcium diphosphide	1305-99-3	Rodenticide [ECHA - Tricalcium diphosphide 2013]
Tebufenpyrad	119168-77-3	Acaricide, insecticide [Pesticides 2013]- no indication of association with plastics
Mandipropamid	374726-62-2	Fungicide [Pesticides 2013]- no indication of association with plastics
Ethephon	16672-87-0	Plant growth regulator [Pesticides 2013]- no indication of association with plastics
Tembotrione	335104-84-2	Herbicide [Pesticides 2013]- no indication of association with plastics
Spirotetramat	203313-25-1	Insecticide [Pesticides 2013]- no indication of association with plastics
Methyl 2,5-dichlorobenzoate	2905-69-3	Fungicide [PAN 2014b]
Fluazinam	79622-59-6	Fungicide [Pesticides 2013]- no indication of association with plastics
Tetrahydrofurfuryl alcohol (THFA)	97-99-4	Intermediate – plastic products [ECHA 2013] Epoxy resin and curing agent formulation [Chemicalland 21 –THFA]
Benzoic acid	65-85-0	Intermediate – production of phenol and plasticisers [SIDS 2001]
Fenpyroximate (ISO); tert-butyl 4-[({[(E)-(1,3-dimethyl-5-phenoxy-1H-pyrazol-4-yl)methylene]amino}oxy)methyl]benzoate	134098-61-6	Acaricide [Pesticides 2013]- no indication of association with plastics
Nonanoic acid	112-05-0	Disinfectant, preservative, repellent [ECHA – nonanoic acid 2013]
Octanoic acid	124-07-2	Insecticide, disinfectant [CLH report –Decanoic acid 2012]. Intermediate – production of amides -> polyamide [Chemicalland 21-caprylic acid] Assessed not to be present in significant concentrations in plastic end products
Decanoic acid	334-48-5	Insecticide, repellent, disinfectant [CLH report – Decanoic acid 2012]. Intermediate – production of amides -> polyamide [Chemicalland 21-capric acid] Assessed not to be present in significant concentrations in plastic end products

Etofenprox	80844-07-1	Insecticide [Pesticides 2013]- no indication of association with plastics
K-HDO	66603-10-9	Wood preservative
Cis-Tricos-9-ene (Muscalure)	27519-02-4	Insect attractants [Pesticides 2013]- no indication of association with plastics
CU-HDO (Bis(N-cyclohexyl-diazenium-dioxy)-copper)	312600-89-8	Not used in plastics
Imazalil	35554-44-0	Fungicide [Pesticides 2013]- no indication of association with plastics
Fenoxaprop-P-ethyl	71283-80-2	Herbicide [Pesticides 2013]- no indication of association with plastics
Cycloxydim	101205-02-1	Herbicide [Pesticides 2013]- no indication of association with plastics
Acrolein	107-02-8	Herbicide [Pesticides 2013]- no indication of association with plastics
Potassium sorbate	24634-61-5	Food preservative
3-Iodo-2-propynylbutylcarbamate	55406-53-6	Fungicide [Pesticides 2013]- no indication of association with plastics
Cymoxanil	57966-95-7	Fungicide [Pesticides 2013]- no indication of association with plastics
1,1',1''-nitrilotripropan-2-ol (TIPA)	122-20-3	Intermediate – manufacture of polyurethane – assessed not to be present in products of PUR
Amidosulfuron	120923-37-7	Herbicide [Pesticides 2013]- no indication of association with plastics
Fenoxycarb	72490-01-8	Insecticide [Pesticides 2013]- no indication of association with plastics
Warfarin (ISO); 4-hydroxy-3-(3-oxo-1-phenylbutyl)-2H-chromen-2-one	81-81-2	Rodenticide [Pesticides 2013]- no indication of association with plastics
Vinylcyclohexene (VCH)	100-40-3	Intermediate - no indication of association with plastics [ECHA 2013]
Brodifacoum (ISO); 4-hydroxy-3-(3-(4'-bromo-4-biphenylyl)- 1,2,3,4-tetrahydro-1-naphthyl)coumarin;	56073-10-0	Rodenticide [Pesticides 2013]- no indication of association with plastics
Perestane	847871-03-8	Disinfectant
Flocoumafen (ISO); reaction mass of: cis-4-hydroxy-3-(1,2,3,4- tetrahydro-3-(4-(4-trifluoromethylbenzyloxy)phenyl)-1-naphthyl)coumarin; trans-4-hydroxy-3-(1,2,3,4-tetrahydro-3-(4- (4-trifluoromethylbenzyloxy)phenyl)-1- naphthyl)coumarin	90035-08-8	Rodenticide [Pesticides 2013]- no indication of association with plastics
Difenacoum (ISO); 3-(3-biphenyl-4-yl-1,2,3,4-tetrahydro-1- naphthyl)-4-hydroxycoumarin	56073-07-5	Rodenticide [Pesticides 2013]- no indication of association with plastics
Difethialone (ISO); 3-[3-(4'-bromobiphenyl-4-yl)-1,2,3,4-tetrahydronaphthalen-1-yl]-4-hydroxy-2H-1-benzothiopyran-2-one	104653-34-1	Rodenticide [Pesticides 2013]- no indication of association with plastics
Bromadiolone (ISO); 3-[3-(4'-bromobiphenyl-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-	28772-56-7	Rodenticide [Pesticides 2013]- no indication of association with plastics

2H-chromen-2-one		
Aluminium phosphide	20859-73-8	Insecticide [Pesticides 2013]- no indication of association with plastics
Trimagnesium diphosphide	12057-74-8	Insecticide [Pesticides 2013]- no indication of association with plastics
Chlorophacinone (ISO); 2-[(4-chlorophenyl)(phenyl)acetyl]-1H-indene-1,3(2H)-dione	3691-35-8	Rodenticide [Pesticides 2013]- no indication of association with plastics
N-ethyl-2-pyrrolidone (NEP) (1-ethylpyrrolidin-2-one)	2687-91-4	Solvent, catalyst and cationic surfactant. Process regulators for polymerisation processes in production of resins, rubbers, polymers [ECHA 2013; CLH report – NEP 2011] - no strong indication of association with plastics
Fenamiphos	22224-92-6	Insecticide, nematicide [Pesticides 2013]- no indication of association with plastics
Indoxacarb	173584-44-6	Insecticide [Pesticides 2013]- no indication of association with plastics
Aluminium-magnesium-zinc-carbonate-hydroxide	169314-88-9	Stabilizer in plastics (PVC) mainly moulded products.
Aclonifen	74070-46-5	Herbicide [Pesticides 2013]- no indication of association with plastics
Sulcotrione	99105-77-8	Herbicide [Pesticides 2013]- no indication of association with plastics
Penconazole	66246-88-6	Fungicide [Pesticides 2013]- no indication of association with plastics
2-Ethoxyethanol	110-80-5	Solvent for nitrocellulose, epoxy coatings, alkyd resins [Ash and Ash, 2007]
Ethylbenzene	100-41-4	Intermediate used for production of styrene -> PS, EPS, XPS, HIPS, ABS etc.
Amines, coco alkyl	61788-46-3	Intermediate – used for manufacture of amino ethoxylates that may be used as additives in plastics [EURAR – Amines 2008]
Amines, Tallow Alkyl	61790-33-8	Intermediate – used for manufacture of amino ethoxylates that may be used as additives in plastics [EURAR – Amines 2008]
Octadecylamine	124-30-1	Intermediate – used for manufacture of amino ethoxylates that may be used as additives in plastics [EURAR – Amines 2008]
Amines, hydrogenated tallow alkyl	61788-45-2	Intermediate – used for manufacture of amino ethoxylates that may be used as additives in plastics [EURAR – Amines 2008]
(Z)-octadec-9-enylamine	112-90-3	Intermediate – used for manufacture of amino ethoxylates that may be used as additives in plastics [EURAR – Amines 2008]
Reaction mass of 2,4,4-Trimethylpent-1-ene and 2,4,4-Trimethylpentene	25167-70-8	Intermediate – no indication of association with plastics

4-tert-butylbenzoic acid	98-73-7	Intermediate - assessed not to be present in significant concentrations in plastic end products
Nitrobenzene	98-95-3	Intermediate – production of aniline etc.
Metazachlor	67129-08-2	Herbicide [Pesticides 2013]- no indication of association with plastics
Leucomalachite Green	129-73-7	Natural metabolite of malachite green - used as a detection method for latent blood in forensic science
Fuberidazole	3878-19-1	Fungicide [Pesticides 2013]- no indication of association with plastics
Bifenthrin	82657-04-3	Acaricide, insecticide [Pesticides 2013]- no indication of association with plastics
Flufenoxuron	101463-69-8	Acaricide, insecticide [Pesticides 2013]- no indication of association with plastics
Acequinocyl	57960-19-7	Acaricide [Pesticides 2013]- no indication of association with plastics
MMTC (trichloride of methyltin)	993-16-8	Intermediate - catalyst used in a conversion of alcohol to ether
EHMA (methyltin tri(2-ethylhexyl-mercaptoacetate MMT)	57583-34-3	Heat stabilizer in PVC [CLH report – MMT(EHMA) 2010]
White spirit type 0, Solvent naphtha (petroleum), medium aliphatic	64742-88-7	Not included – see Danish list of undesired substances
Stoddard solvent (US term for white spirit, corresponding to white spirit type 1; see CAS-no. 64742-82-1)	8052-41-3	Not included – see Danish list of undesired substances
White spirit type 1, Naphtha (petroleum), hydrodesulphurised heavy	64742-82-1	Not included – See Stoddard solvent above
Abamectin	71751-41-2	Acaricide, insecticide, nematicide [Pesticides 2013]- no indication of association with plastics
Cryolite (Trisodium hexafluroaluminate)	15096-52-3	Production of aluminium etc. - no indication of association with plastics
Cryolite (Trisodium hexafluoroaluminate)	13775-53-6	Production of aluminium etc. - no indication of association with plastics
Indium phosphide	22398-80-0	Semiconductor
Chloroform	67-66-3	Not included – see List of CMR-substances in toy
Tetrahydrofuran	109-99-9	THF is used as a solvent for a variety of plastics, dyes, elastomers, etc., as a glue in joining plastics components [Annex VI report-THF]
Di-tert-butylperoxide	110-05-4	Intermediate - process regulators for polymerisation processes in production of resins, rubbers, polymers [ECHA 2013]
Diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide	75980-60-8	Intermediate - process regulators for polymerisation processes in production of resins, rubbers, polymers [ECHA 2013]
Epoxiconazole	133855-98-8 (Formerly 106325-08-0)	Fungicide [Pesticides 2013]- no indication of association with plastics

Imidazolidine-2-thione; 2-imidazoline-2-thiol	96-45-7	Used for vulcanisation of rubber - not used in plastics [Annex XV - imidazolidine-2-thione]
Disodium 4-amino-3-[[4'-[(2,4-diaminophenyl)azo][1,1'-biphenyl]-4-yl]azo] -5-hydroxy-6-(phenylazo)naphthalene-2,7-disulphonate (C.I. Direct Black 38)	1937-37-7	Dye used for cotton, viscose, silk, polyamide fiber and its blending fabric, leather, wood, biological and plastic colour, also used as the raw material of black ink [Dye – Direct Black]
Disodium 3,3'-[[1,1'-biphenyl]-4,4'-diylbis(azo)]bis(4-aminonaphthalene-1-sulphonate) (C.I. Direct Red 28)	573-58-0	Dying of viscose, cotton, wool, silk cellulose fibres [Dye – Direct red]
Dipentyl phthalate (DPP)	131-18-0	Not included – see candidate list
Diethyl sulphate	64-67-5	Not included – see candidate list
Dimethyl sulphate	77-78-1	Not included – see candidate list
6-methoxy-m-toluidine (p-cresidine)	120-71-8	Not included – see candidate list
4,4'-methylenedi-o-toluidine	838-88-0	Not included – see candidate list
N-methylacetamide	79-16-3	Not included – see candidate list
1-bromopropane (n-propyl bromide)	106-94-5	Not included – see candidate list
4,4'-oxydianiline and its salts	101-80-4	Not included – see candidate list
Biphenyl-4-ylamine	92-67-1	Not included – see candidate list
Dinoseb (6-sec-butyl-2,4-dinitrophenol)	88-85-7	Not included – see candidate list
4-Aminoazobenzene	60-09-3	Not included – see candidate list
o-aminoazotoluene	97-56-3	Not included – see candidate list
Furan	110-00-9	Not included – see candidate list
3-ethyl-2-methyl-2-(3-methylbutyl)-1,3-oxazolidine	143860-04-2	Not included – see candidate list
o-Toluidine	95-53-4	Not included – see candidate list
4-methyl-m-phenylenediamine (toluene-2,4-diamine)	95-80-7	Not included - see candidate list
N-pentyl-isopentylphthalate	776297-69-9	Not included – see candidate list
Methoxyacetic acid	625-45-6	Not included – see candidate list
1,2-Benzenedicarboxylic acid, dipentylester, branched and linear	84777-06-0	Not included – see candidate list
1,2-Diethoxyethane	629-14-1	Not included – see candidate list
[4-[4,4'-bis(dimethylamino) benzhydrylidene]cyclohexa-2,5-dien-1-ylidene]dimethylammonium chloride (C.I. Basic Violet 3) [with â‰¥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	548-62-9	Dye in various materials inclusive of rubber and textiles - violet colours - dyes are not included
4,4'-bis(dimethylamino)-4''-(methylamino)trityl alcohol [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	561-41-1	Not included – see candidate list
α,α-Bis[4-(dimethylamino)phenyl]-4 (phenylamino)naphthalene-1-methanol (C.I. Solvent Blue 4) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-	6786-83-0	Not included – see candidate list

959-2)]		
4,4'-bis(dimethylamino) benzophenone (Michler's ketone)	90-94-8	Not included – see candidate list
N,N,N',N'-tetramethyl-4,4'-methylenedianiline (Michler's base)	101-61-1	Not included – see candidate list
[4-[[4-anilino-1-naphthyl][4-(dimethylamino)phenyl]methylene]cyclohexa-2,5-dien-1-ylidene] dimethylammonium chloride (C.I. Basic Blue 26) [with ≥ 0.1% of Michler's ketone (EC No. 202-027-5) or Michler's base (EC No. 202-959-2)]	2580-56-5	Not included – see candidate list
Formamide	75-12-7	Not included – see candidate list
Diboron trioxide	1303-86-2	Not included – see candidate list
1,2-bis(2-methoxyethoxy)ethane (TEGDME; triglyme)	112-49-2	Not included – see candidate list
1,2-dimethoxyethane; ethylene glycol dimethyl ether (EGDME)	110-71-4	Not included – see candidate list
1,2-Dichloroethane	107-06-2	Not included – see candidate list
N,N-dimethylacetamide (DMAC)	127-19-5	Not included – see candidate list
Bis(2-methoxyethyl) ether	111-96-6	Not included – see candidate list
Aluminosilicate Refractory Ceramic Fibres		Not included – see candidate list
Phenolphthalein	77-09-8	Not included – see candidate list
Zirconia Aluminosilicate Refractory Ceramic Fibres…		Not included – see candidate list
2-Methoxyaniline o-Anisidin	90-04-0	Not included – see candidate list
1-Methyl-2-pyrrolidone (NMP)	872-50-4	Not included – see candidate list
Cobalt dichloride	7646-79-9	Not included – see candidate list
2-Ethoxyethyl acetate	111-15-9	Not included – see candidate list
Cobalt(II) carbonate	513-79-1	Not included – see candidate list
Cobalt(II) dinitrate	10141-05-6	Not included – see candidate list
Cobalt(II) sulphate	10124-43-3	Not included – see candidate list
Trichlorobenzene	120-82-1	Not included – see candidate list
1,3,5 Trichlorobenzene	108-70-3	Intermediate and process solvent in closed systems - in addition solvent, dye carrier, corrosion inhibitor and lubricant [Annex XV – TCB] - no indication of use related to plastics
1,2,3 Trichlorobenzene	87-61-6	Intermediate and process solvent in closed systems - in addition solvent, dye carrier, corrosion inhibitor and lubricant [Annex XV – TCB] - no indication of use related to plastics
	110-80-5	Not included – see candidate list
Tetraboron disodium heptaoxide, hydrate	12267-73-1	Not included – see candidate list
2,4-Dinitrotoluene	121-14-2	Not included – see candidate list
5-tert-butyl-2,4,6-trinitro-m-xylene (musk xylene)	81-15-2	Not included – see candidate list
Cyclododecane	294-62-2	Intermediate for production of chemicals used to make

		polyamides, polyesters, synthetic lubricating oils, nylon and high purity solvents [Annex XV – cyclodecane] - amount of potential residues in plastics assumed to be in- significant
1,4-Dichlorobenzene (p-dichlorobenzene)	106-46-7	Placing on the market of air fresheners and toilet blocks containing DCB
Dimethylfumarate	624-49-7	Placing on the market of articles containing Dimethylfumarate DMFu seems to be used for mould preservation of textiles - it has been registered in furniture foam in low concentrations probably due to contamination [Annex XV restriction report – DMFu]
Triadimenol (ISO); 1-(4-chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl)butan-2-ol	55219-65-3	Fungicide [Pesticides 2013]- no indication of association with plastics
Terbuthylazine (N2-tert-butyl-6-chloro-N4-ethyl-1,3,5-triazine-2,4-diamine)	5915-41-3	Herbicide [Pesticides 2013]- no indication of association with plastics
Spirodiclofen (ISO); 3-(2,4-dichlorophenyl)-2-oxo-1-oxaspiro[4.5]dec-3-en-4-yl 2,2-dimethylbutyrate	148477-71-8	Acaricide [Pesticides 2013]- no indication of association with plastics
Sodium hypochlorite	7681-52-9	Not included – see Danish list on undesired substances
Quizalofop-P-terfuryl; (RS)-Tetrahydrofurfuryl (R)-2-[4-(6-chloroquinoxalin-2-yloxy)phenoxy]propionate	119738-06-6	Herbicide [Pesticides 2013] - no indication of association with plastics
Pymetrozine (ISO); (E)-4,5-dihydro-6-methyl-4-(3-pyridylmethyleneamino)-1,2,4-triazin-3(2H)-one	123312-89-0	Antifeedants [Pesticides 2013] - no indication of association with plastics
Peroxyoctanoic acid	33734-57-5	Pesticide
N,N-diethyl-m-toluamide; deet	134-62-3	Insect repellent [Pesticides 2013]- no indication of association with plastics
Mixture of 5-chloro-2-methylisothiazol-3(2H)-one and 2-methylisothiazol-3(2H)-one	55965-84-9	For veterinary diagnostic use
Metofluthrin	240494-70-6	Insecticide [Pesticides 2013]- no indication of association with plastics
Margosa extract from the kernels of Azadirachta indica extracted with water and further processed with organic solvents	84696-25-3	Natural repellent - no indication of association with plastics
IDS, NA-SALZ	-	Sodium iminodisuccinate (IDS) belongs to the group of aminopolycarboxylate chelating agents - IDS is a medium-strong chelator that is able to replace EDTA - IDS as a substitute for EDTA is used in a variety of applications, including detergent formulations, corrosion inhibitors, production of pulp and paper, textiles, ceramics, photochemical processes, and as trace nutrient fertilizers in agriculture [Cokesa et al 2004]
Hymexazol (ISO); 3-hydroxy-5-methylisoxazole	10004-44-1	Fungicide, plant growth regulator [Pesticides 2013]- no indication of association with plastics
Dimethyl (2aR,3S,4S,4aR,5S,7aS,8S,10R,10aS,10bR)-10-acetoxy-3,5-dihydroxy-4-	11141-17-6	Insecticide [Pesticides 2013]- no indication of association with plastics

[(1aR,2S,3aS,6aS,7S,7aS)-6a-hydroxy-7a-methyl-3a,6a,7,7a-tetrahydro-2,7-methanofuro[2,3-b]oxireno[e]oxepin-1a(2H)-yl]-4-methyl-8-{[(2E)-2-methylbut-2-enoyl]oxy}octahydro-1H-naphtho[1,8a-c:4,5-b'c']difuran-5,10a(8H)-dicarboxylate		
Cyanamide	420-04-2	Intermediate – plant growth initiator - no indication of association with plastics
Chlorsulfuron (ISO); 2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulphonamide	64902-72-3	Herbicide [Pesticides 2013]- no indication of association with plastics
Carboxin (5,6-dihydro-2-methyl-1,4-oxathiine-3-carboxanilide)	5234-68-4	Fungicide [Pesticides 2013]- no indication of association with plastics
4-Chloro-3-methylphenol	59-50-7	Disinfectant - no indication of association with plastics
2-methylisothiazol-3(2H)-one	2682-20-4	Preservative - no indication of association with plastics
Chrysotile	12001-29-5, 132207-32-0	The substance is a kind of asbestos fibres. The use is not related to plastics
Benzovindiflupyr (ISO); N-[9-(dichloromethylene)-1,2,3,4-tetrahydro-1,4-methanonaphthalen-5-yl]-3-(difluoromethyl)-1-methyl-1H-pyrazole-4-carboxamide	1072957-71-1	Fungicide [PAN 2014a]- no indication of association with plastics

CMR-substances in plastic toys

Chemical name	CAS No	Major use	Function	Occurrence
Acetamide	60-35-5	Plasticiser for wood – not relevant for plastic		
Nickel	7440-02-0	Nickel plating; for various alloys such as new silver, Chinese silver, German silver; for coins, electrotypes, lightning rod tips, electrical contacts and electrodes, spark plugs, machinery parts (Merck Index)	Surface coating	Metallic microstructured coatings
4,4'-carbonimidoylbis[*N*,*N*-dimethylaniline]	492-80-8	Dye for paper, cardboard, textiles, leather, oils, waxes, alcoholic solvents, lacquers, pen inks, carbon papers, & typewriter ribbons	Colorant	Paper Cardboard Leather Textiles Coatings
4-[4,4'-bis(dimethylamino) benzhydrylidene]cyclohexa-2,5-dien-1-ylidene]dimethylammonium chloride, C.I. Basic Violet 3	548-62-9	As a dye for wood, silk, paper; in inks; as a biological stain	Colorant	Violet coloured plastics, rubbers (2%) and textiles (6-8%) - dyes are not included
Benzyl violet 4B, α-[4-(4-dimethylamino-α-{4-[ethyl(3-sodiosulphonatobenzyl)amino] phenyl}benzylidene)cyclohexa-2,5-	1694-09-3	Dye for wool, nylon, leather, anodized aluminium, inks, & paper; biological & wood stain	Colorant	Violet coloured polymers

dienylidene(ethyl)ammonio]toluene-3-sulphonate				
2-butanon oxime	96-29-7	Viscosity regulation in paint and lacquer - liberated from neutral cure silicones during cure	Degradation product Solvent	Silicone rubber, neutral cured
Thiocarbamide, thiourea	62-56-6	Photographic toning agent, fixing agent and chemicals; Flame-retardant textile sizes; Flame-retardant finish for cotton; Imparting flame resistance and improved handling properties for nylon-based products	Chemical Intermediate for plastic and artificial silk Curing agent (Merck Index)	Rubber vulcanized with thiourea Cotton, flamaretarded
4-aminophenol	123-30-8	Dyeing textiles, hair, furs, feathers; photographic developer	Chemical Intermediate for rubbers (Rapra Toxic prop)	
Aniline	62-53-3	Precursor to MDI used for manufacturing of PUR	Chemical Intermediate Degradation product	
Ethylen thiourea 2 imidazoline thione	96-45-7	Accelerator for CR rubber. Former the most common used accelerator for CR	Curing agent	CR rubber
Nickelsulphide	16812-54-7	Possible degradation product in rubber vulcanized with dithiocarbamin acid nickel salts	Degradation product	Rubber vulcanized with nickel dithiocarbamates
p-chloro-anilin	106-47-8		Chemical intermediate	
o-anisidin /p-anisidin	104-94-9		Chemical intermediate	
Benzene	71-43-2		Solvent	
Octamethylcyclotetrasiloxane	556-67-2	Component of silicone fluid mixtures; widespread use in a variety of applications including fermentation processes, instant coffee production, paper coatings and sizing, diet soft drinks, waste yeast tanks, food washing solutions, adhesives, textiles, deasphalting, boiler treatments, detergents, cleaning solutions, surfactants, cosmetic products, and polishes	Plasticiser Surfactant	Silicone rubber, water repellent coatings
m-phenylenediamine	108-45-2	Dyestuff manufacture, detection of nitrite, textile developing agent, laboratory reagent, vulcanizing agent – rubber chemicals	Vulcanisation agent, curing agent, chemical Intermediate for dyes	Paint, dyestuffs ,coatings, rubbers, epoxies

1,3-diphenylguanidine	102-06-7	Vulcanization accelerator for natural and synthetic rubbers - 0.25-2.0 pphr. - non-staining	Curing agent	Rubbers
1,2,3,6-tetrahydro-*N*-(trichloromethyl-thio)phthalimide, captan (ISO)	133-06-2	Industrial uses include incorporation into lacquers, paints (oil based), paper, paste (wallpaper flour), plasticisers, polyethylene, rubber stabilizer, textiles, vinyl, and vinyl resins- - biocide in soap	Biocide	Paints, coatings Paper Rubber
1,4-dihydroxybenzene, hydroquinone, quinol	123-31-9	Used as a raw material to produce rubber antioxidants for fats & oils, polymerization inhibitor; stabilizer in paints; varnishes, motor fuels & oils; in human medicine for skin blemishes; chemical intermediate for dyes	Chemical intermediate Antioxidant	
1,2,3-trihydroxybenzene, pyrogallol	87-66-1	Developer in photography; as mordant for wool; staining leather; process engraving; manufacturing of various dyes; dyeing furs, hair	Chemical Intermediate for dyes	Wool textile Leather
Toluene	108-88-3	In manufacture benzoic acid, benzaldehyde, explosives, dyes, and many other organic compounds; as a solvent for paints, lacquers, gums, resins, in the extraction of various principles from plants; as gasoline additive; in fabric and paper coating, manufacture of artificial leather	Solvent	
Formamide	75-12-7	Degradation product from rubber accelerator	Degradation product	Vulcanized rubber
Carbon disulphide	75-15-0	Paints, rubber cement, vulcanized rubber, paper manufacture	Degradation product	Sulphur cured rubbers - especially thiuram and dithiocarbamate cured
Ethandial...%, glyoxal...%	107-22-2	In paper industry for sizing, washable wall paper, treating glue surface of envelopes; in textile industry for preventing shrinking and creasing; as substitute for formaldehyde in embalming	Biocide	Paper and carton Biocide treated textiles

		fluids		
Naphthalene	91-20-3	Used in the production of plastics and vulcanizes	Chemical intermediate	Trace pollutant in polymers
3-chloropropene, allyl chloride	107-05-1	Synthesis of intermediates for manufacture of polymers, resins & plastics	Chemical intermediate	Trace pollutant in some allyl based polymers
Acetaldehyde, ethanal	75-07-0	Mfr paraldehyde, acetic acid, butanol, perfumes, aniline dyes, plastics, synthetic rubber, silvering mirrors, hardening gelatin fibers (Merck Index)	Chemical intermediate	Trace pollutant in polymers
2-butenal, crotonaldehyde [1] (*E*)-2-butenal, (*E*)-crotonaldehyde [2]	4170-30-3 [1] 123-73-9 [2]	Minor amounts are used in the manufacture of maleic acid, crotyl alcohol, butyl chloral hydrate, and in rubber accelerators. In organic syntheses; as solvent in purification of mineral oils, manufacture of resins, rubber antioxidants, insecticides	Chemical Intermediate Solvent	Trace pollutant in polymers
2-furaldehyde	98-01-1	Source of furfuryl alcohol, tetrahydrofurfuryl alcohol, furan, tetrahydrofuran, poly(oxytetramethylene) glycol and a variety of synthetic resins; for the extractive distillation of butadiene and other C4 hydrocarbons for the manufacture of synthetic rubber; and for the production of light-coloured wood resins	Chemical intermediate	Trace pollutant in polymers and light coloured wood resins
1-chloro-4-nitrobenzene	100-00-5	Used in production of rubber chemicals	Chemical Intermediate	
n-hexane	110-54-3	Solvent, especially for vegetable oils; low-temperature thermometers; calibrations; polymerization reaction medium; paint diluent; alcohol denaturant	Solvent	Paints/coatings Glues

Chloroform, trichloromethane	67-66-3	As a solvent for coating compositions of urea or melamine resins and for preparations of lubricant additives and plasticisers; surface-active agents; lubricant additives, rubber chemicals, flotation agents, anti-foam agent; flavouring agent; reaction medium for hydrogen pyroxide production; defoamer	Solvent	Trace pollutant in paints/coatings and glues
Carbon tetrachloride, tetrachloro-methane	56-23-5	Powerful solvent for asphalt, benzyl resin, bitumen, chlorinated rubber, ethylcellulose, gums, and rosin	Solvent	Trace pollutant in paints/coatings and glues
Chloroethane	75-00-3	Use in manufacture of dyes and drugs, use as a propellant in aerosols	Solvent	Trace pollutant in paints/coatings and glues
Pentachloroethane	76-01-7	Pentachloroethane is used as a solvent for cellulose acetate, certain cellulose ethers, resins and gums. Pentachloroethane is also used as a drying agent for timber /immersed in it/ at temperatures greater than 100 °C	Solvent	Paints/coatings /glues
1-vinyl-2-pyrrolidone	88-12-0	Solvent for resins, co-monomer for polymerization, binder in cosmetic and pharmaceutical preparations	Solvent	Trace pollutant in polymers
Tetrachloroethylene	127-18-4	Intermediate for chloro-fluorocarbons, dry cleaning, degreasing etc.	Solvent	Paints, coatings, glues
2-hexanon	591-78-6			Trace amounts in rubber
2-Ethoxyethyl acetate	111-15-9	Solvent for lacquers	Solvent	Coatings
Isoprene	78-79-5	Monomer for isoprene rubber and butylrubber	Monomer	

Alternative plasticisers and flame retardants

Substance	CAS No.	Use associated with plastic
Brominated epoxy resin end-capped with tribromophenol	135229-48-0	Polymer
Brominated polyacrylate	59447-57-3	Polymer
Brominated polystyrene	88497-56-7	Polymer
TBBPA glycidyl ether, TBBPA poly-	68928-70-1	Polymer

mer		
Benzene, ethenyl-, polymer with 1,3-butadiene, brominated	1195978-93-8	EPS, XPS, polymer

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Annex XV reports for Candidate list substances.
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Hazardous substances in plastics

The report presents information on hazardous substances in plastics including information on the function and application of the substances in plastics as well as on potential for migration and fate by recycling of plastics. 132 chemical substances or substance groups are identified as being potentially present in plastic and these substances could have hazardous properties. For these substances or substance groups information has been collected, assessed and presented to the extent, it has been available. The following issues have been addressed; technical function (of the substance), relevant types of plastics (where the substance is used), main articles groups (for which the plastics with the substance are used), potential for release from plastics (will it migrate?), potential for exposure of consumers and fate by recycling.

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