Study on Hazardous Substances in Electrical and Electronic Equipment, Not Regulated by the RoHS Directive

Final Report

- Draft -

Freiburg, 28.04.2008

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Glossary

ABS	Acrylonitrile-butadiene-styrene
AOH	Aluminium-oxide-hydroxide
ATH	Aluminium-tri-hydroxide
BBP	Butyl benzyl phthalate
BCF	Bioconcentration factor
BDP	Bis-phenol A bis(diphenyl phosphate)
BFR	Brominated flame retardant
Carc. Cat	Carcinogenic category 1, 2 or 3
CBD	Chronic beryllium disease
CMR	Cancerogenic, mutagenic and reprotoxic
CRT	Cathode ray tube
DBP	Dibutylphthalate
DEHP	Bis (2-ethylhexyl) phthalate
DG ENTR	Directorate General Enterprise and Industry
DG ENV	Directorate General Environment
DIDP	1,2-Benzenedicarboxylic acid diisodecyl ester
DINP	Diisononyl phthalate
DNOP	Di-n-octyl phthalate
DOPO	Dihydrooxaphosphaphenantrene
EEE	Electrical and electronic equipment
EPS	Expanded polystyrene
EU RAR	EU risk assessment report
HBCDD	Hexabromocyclododecane
HIPS	High impact polystyrene
LCD	Liquid crystal display
MCCP	Medium-chained chlorinated paraffins
Mut. Cat	Mutagenic category 1, 2 or 3:
N	Dangerous for the environment
OSPAR	Commission for the Protection of the Marine Environment of the North-East Atlantic
PBB	Polybrominated biphenyls
PBDD	Polybrominated dibenzo-p-dioxin

PBDE	Polybrominated diphenyl ethers
PBDF	Polybrominated dibenzofurans
PBT	Persistent and bioaccumulative and toxic
PC	Polycarbonate
PCB	Printed circuit board
PEI	Polyether imide
PES	Polyethersulfone
POP	Persistent organic pollutants
PPO	Polyphenylene oxide
PVC	Polyvinylchloride
PWB	Printed wiring board
REACH	Regulation 1907/2006/EC concerning the registration, evaluation, authorisation and restriction of chemicals (REACH)
RDP	Resorcinol bis (diphenyl phosphate)
Repr. Cat	Toxic for Reproduction Category 1, 2, or 3
RoHS (Directive)	(Directive 2002/95/EC on the) restriction of the use of certain hazardous substances in electrical and electronic equipment
TPP	Tri-phenyl phosphate
SCCPs	Short-chained chlorinated paraffins
SMEs	Small and medium-sized enterprises
SVHC	Substances of very high concern
TBBP-A	Tetrabromobisphenol-A
tpa	Tonnes per year
VECAP	Voluntary Emissions Control Action Programme
vPvB	Very persistent and very bioaccumulative
WEEE (Directive)	(Directive 2002/96/EC on) waste electrical and electronic equipment
XPS	Extruded polystyrene
XRF	X-ray fluorescence analysis
ZVEI	German Electrical and Electronic Manufacturers Association

1 Background and objectives

Following the requirements of Article 4 (1) of the Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive), Member States of the European Union have to ensure that “from 1 July 2006, new electrical and electronic equipment (EEE) put on the market does not contain lead, mercury, cadmium, hexavalent chromium, PBB or PBDE.” The Annex to the Directive lists a limited number of applications of lead, mercury, cadmium and hexavalent chromium, which are exempted from the requirements of Article 4 (1).

Article 4 (3) mentions that “as soon as scientific evidence is available, and in accordance with the principles on chemicals policy” EU bodies shall decide on the prohibition of other hazardous substances and the substitution thereof by more environment-friendly alternatives which ensure at least the same level of protection for consumers.

Under Article 6 it is provided that the Commission has to review the list of restricted substances in Article 4 (1) on the basis of scientific facts and taking the precautionary principle into account. In particular, the Commission has to present proposals for the inclusion of equipment which falls under categories 8 and 9 set out in Annex IA to Directive 2002/96/EC (WEEE Directive)[1] into the scope of this Directive. It is further mentioned, that particular attention shall be given to impacts on the environment and human health of other hazardous substances and materials used in EEE, and that the Commission shall examine feasibility of replacing such substances and materials. It shall then “present proposals to the European Parliament and to the Council in order to extend the scope of Article 4 as appropriate”.

The objective of the present study is thus to provide the necessary support to the Commission services for fulfilling RoHS Article 6 requirements, including investigation on:

- Other hazardous substances or materials used in EEE;
- How they are managed currently;
- Possible substitutes as well as the sustainability (environmental, economic, social) characteristics of these other hazardous substances and possible substitutes;
- Policy options for each substance considered as a candidate for an inclusion into the RoHS Directive.

As such, the study forms an integral part of the RoHS review process that is currently being carried out by the Commission: it started in 2006 and is to be finalised in 2008. Inter alia, the Commission has consulted stakeholders on different policy options which are thought of for

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[1] Categories 8 and 9 set out in Annex IA to the WEEE Directive comprise medical devices (with the exception of all implanted and infected products) as well as monitoring and control instruments, respectively.

the overall review of the Directive. Concerning the substances covered by the Directive, eight different (preliminary) policy options have been proposed. They are in line with the key options analysed in the present study. The Commission has received 50 contributions in total. Stakeholder contributions related to the hazardous substances to be covered under RoHS have been taken into consideration for the development of proposals within this study. Opinions of stakeholders varied as to whether new substances should be completely dealt with under REACH (option 1), whether they should be added for all EEE with exempted applications (option 3), or whether a more differentiated approach should be chosen, depending on the outcome e.g. of ongoing discussions around the implication of REACH with regard to substances in Articles (especially the provision of Article 7(2)).

Furthermore, through a possible widening of the scope of the Directive by adding more substances that are to be banned in EEE, the present study will also contribute to other studies that are carried out in the context of the RoHS review: BIO-IS is currently carrying out a study on behalf of DG ENV to support the impact assessment of the RoHS review. The present analysis on the possible inclusion of additional hazardous substances in the scope of RoHS is closely linked with that study. An exchange will take place between the two contractors in order to discuss data gap issues and in order to possibly identify potential additional data sources.

Furthermore, the study carried out by ERA on the inclusion of category 8 and 9 WEEE – which is also part of the review process – has been evaluated with regard to possible additional hazardous substances.

On behalf of DG ENTR, a consultant has performed a study on the simplification of both WEEE and RoHS Directives. Since the simplification also targets the substances covered by the RoHS Directive, this study was also taken into consideration against the background of proposed options within the present study.

This study is being carried out by the Öko-Institut e.V. between October 2007 and June 2008. The project tasks are performed in close co-operation with the European Commission and stakeholders (manufacturers, retailers and distributors of EEE and its associations, NGOs, independent experts, etc.).

This final report gives an overview on the results gathered during the investigations on hazardous substances in EEE including a proposal of candidate substances for a potential inclusion in RoHS and elaboration of policy options for each candidate.

Chapter 2 describes the procedure of establishing an inventory of hazardous substances in EEE. After giving an overview on the general approach and a definition of the term “hazardous substances”, the different information sources that were used to set-up the inventory are described. A list of hazardous substances in EEE is presented.

In Chapter 0, the hazardous substances contained in EEE are characterised and discussed in detail with regard to their use in EEE, the legislations under which the substances are currently managed, their hazard classification, and the risk for the environment and human health arising from the use of the hazardous substances in the different life stages of EEE.

In Chapter 4, the candidate substances for a potential inclusion in RoHS are presented, and the facts that argue for an inclusion of these substances in RoHS are discussed. Chapter 5 summarises information on potential substitutes to the candidate substances and in Chapter 6 policy options are elaborated for each candidate substance. Open points that need further clarification are listed in Chapter 7.

2 Inventory of other hazardous substances in EEE

2.1 Definition of potential dangerous and hazardous substances in the context of RoHS Review

Hazardous substances are those substances that meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC, that meet the criteria for PBT / vPvB, or that meet the criteria for evidence of endocrine disruption.

Annex I of Directive 67/548/EEC contains the official list of harmonised classification and labelling (for substances or groups of substances) which is legally binding with the EU. This list is regularly updated through adaptations to technical progress, with the 29th Amendment to Technical Progress[2] being the present valid adaptation.

The EU Working Group on PBT substances[3] set up a list of so-called PBT (persistent and bioaccumulative and toxic) as well as vPvB (very persistent and very bioaccumulative) substances. The criteria for identification of PBT/vPvB substances are set in the Technical Guidance Document (2003)[4] and in Annex XIII of Regulation (EC) No 1907/2006 (REACH Regulation)[5]. The numeric criteria for PBT and vPvB substances are summarised in Annex I (Section 9.1).

In order to address the potential environmental and health impacts of endocrine disruption, the European Community adopted in 1999 a “Community Strategy for Endocrine Disrupters”.

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[2] Commission Directive 2004/73/EC of 29 April 2004 adapting to technical progress for the 29th time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances

[3] In the context of the implementation of Directive 6548 (New Substances) and Regulation 793/93 (Existing Substances), a Technical Committee on New and Existing Substances (TCNES) has been established. This committee has a sub-group on PBT and vPvB substances.

[4] http://ecb.jrc.it/tgdoc/

[5] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

Substances were assigned to one of three categories (Category 1: clear evidence of endocrine disrupting activity [evidence of endocrine disrupting activity in at least one species using intact animals]; Category 2: some evidence suggesting potential activity [at least some in vitro evidence of biological activity related to endocrine disruption]; Category 3: no evidence of endocrine disrupting activity or no data available)[6].

Not all substances listed in Annex I of Directive 67/548/EEC, or classified as PBT/vPvB, or showing evidence of endocrine disruption are of relevance to EEE. Furthermore, some of these substances have already been regulated by RoHS. Therefore, the existing lists were shortened to those substances that may be relevant for EEE by taking out those substances that

- have already been regulated by RoHS (lead, mercury, cadmium, hexavalent chromium, PBB and PBDE);
- are mixtures of hydrocarbons from oil processing (fuels, gas oil, solvent naphtha and further petrol fractions like coal tar);
- are unlikely to be present in EEE, such as volatile organic compounds, hydrogen, sodium carbonate.

In addition to the hazardous substances described above, there are a number of substances not classified as hazardous which can cause harm to man and the environment. These substances can be described as “potentially dangerous substances”. Examples for this are substances – present in electric and electronical equipment - which can form dangerous degradation or reaction products during their life cycle (including waste collection and waste treatment) or which have been found as contaminants in humans and other biota due to their persistency and their potential to bioaccumulate, such as Tetrabromobisphenol-A and Hexabromocyclododecane.

2.2 Information sources

For the establishment of the inventory of hazardous substances in EEE different sources of information on hazardous substances in EEE were evaluated:

- In a stakeholder consultation running from 17 December 2007 to 28 March 2008 manufacturers and suppliers of EEE were asked to specify which hazardous substances / materials are contained in the electrical and electronic components that they manufacture / supply. They were further asked to specify the concentration ranges of the hazardous substances / materials in EEE.

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[6] http://ec.europa.eu/environment/endocrine/strategy/being_en.htm

- Umbrella Specifications: manufacturers of components organised in the Electronic Components Division within the German Electrical and Electronic Manufacturers Association (ZVEI) developed product data sheets for product families, so-called “umbrella specifications”.
- X-ray fluorescence analysis of EEE.
- Screening of study reports on hazardous substances in EEE and related documents.
- Screening of companies’ lists of banned and restricted substances.
- Expert talks with manufacturers, NGOs and research institutes; an overview of all meetings is given in section 9.9 in the Annex.

2.2.1 Industry information

A stakeholder consultation was launched on 17 December 2007 running until 28 March 2008 asking manufacturers and suppliers of EEE for detailed information on hazardous substances in EEE, not regulated by RoHS, in electrical and electronic components.

For this purpose typical components were specified for different electrical and electronic product families on basis of Umbrella Specs published by the German Electrical and Electronic Manufacturers Association (ZVEI). This component structure is presented in Section 9.2. Manufacturers and suppliers of EEE were asked to identify those electrical and electronic components that they produce/supply and to specify which hazardous substances are contained in the specified typical components. Furthermore they should quantify the concentration ranges of hazardous substances in the components and the quantity of electrical and electronic components produced or used per year [e.g. expressed in kg or t per year] as well as the function of the hazardous substance in the component. The questionnaire is presented in Section 9.3.

All stakeholders were invited to complete the component structure list by defining further groups/subgroups/typical components or to adapt the defined groups/subgroups/typical components according to their needs.

Only limited information was received by manufacturers and suppliers through the first questionnaire. In order to be able to set up an inventory of hazardous substances used in EEE further sources of information (i.e. existing studies, XRF-analyses and other information) were evaluated in addition to the questionnaire (see sections 2.2.2, 2.2.3, and 2.2.4). As a first result of these activities, a preliminary inventory of hazardous substances in electrical and electronic components was set up. The hazardous substances in the inventory were grouped in classes of different priority: Substances classified as CMR, PBT / vPvB or endocrine disruptors were allocated a high priority, as well as a number of other substances whose use in EEE and other consumer products was intensively discussed by national authorities, or which are included in the Water Frame Work Directive, OSPAR, etc. The resulting list of hazardous substances in EEE comprised 46 substances/materials. Due to the fact that only limited information had been provided on hazardous substances in EEE during the first part of the stakeholder consultation, the consultation was continued by circulating the list of these 46 hazardous substances asking for further details:

- in which specific components are the hazardous substances contained;
- what are the concentration ranges of the substances in electrical and electronic components;
- is there information on possible substitutes / alternatives.

The purpose of the second part of the consultation was to get more detailed information on the pre-selected hazardous substances to be able to judge whether or not these substances need a further in-depth evaluation.

All comments received on the 46 substances were published on the project website http://hse-rohs.oeko.info and are summarised in the Appendix to the report "Compendium of Comments to Stakeholder Consultation on Hazardous Substances not Regulated by RoHS (28 March 2008)".

2.2.2 Umbrella Specifications

The Electronic Components Division within the German Electrical and Electronic Manufacturers Association (ZVEI) together with the industrial partners has developed the so-called "Umbrella Specifications" for material specifications of electronic components, sub-assemblies and assemblies. The Umbrella Specifications aim to comply with the request of customers for detailed material specifications on individual electronic components, semiconductors, passive components, printed circuit boards, and electromechanical components.

Furthermore, the Umbrella Specifications were developed against the background of the International Material Data System (IMDS) introduced by the automotive industry. While the IMDS requires material contents data in IMDS format for each individual component, the Umbrella Specifications are based on the presentation of special product families with typical characteristics, whereby the number of varying inputs will be drastically reduced. The Umbrella Specifications were elaborated jointly by a number of electronic component manufacturers.

The following figure demonstrates the basis structure of the Umbrella Specifications:

Company logo, optional

Product Content Sheet

Package family		Picture of typical product, optional
Date		
Version		

Composition part	Material group	Materials	CAS if applicable	Average mass [weight-%] *)	Sum [%]	Traces
				Sum in total:		

Weight range	
Fluctuation margin	

or:

Case sizes**) and weight range

*) related to package weight; weight in particular, see corresponding *package weight list*

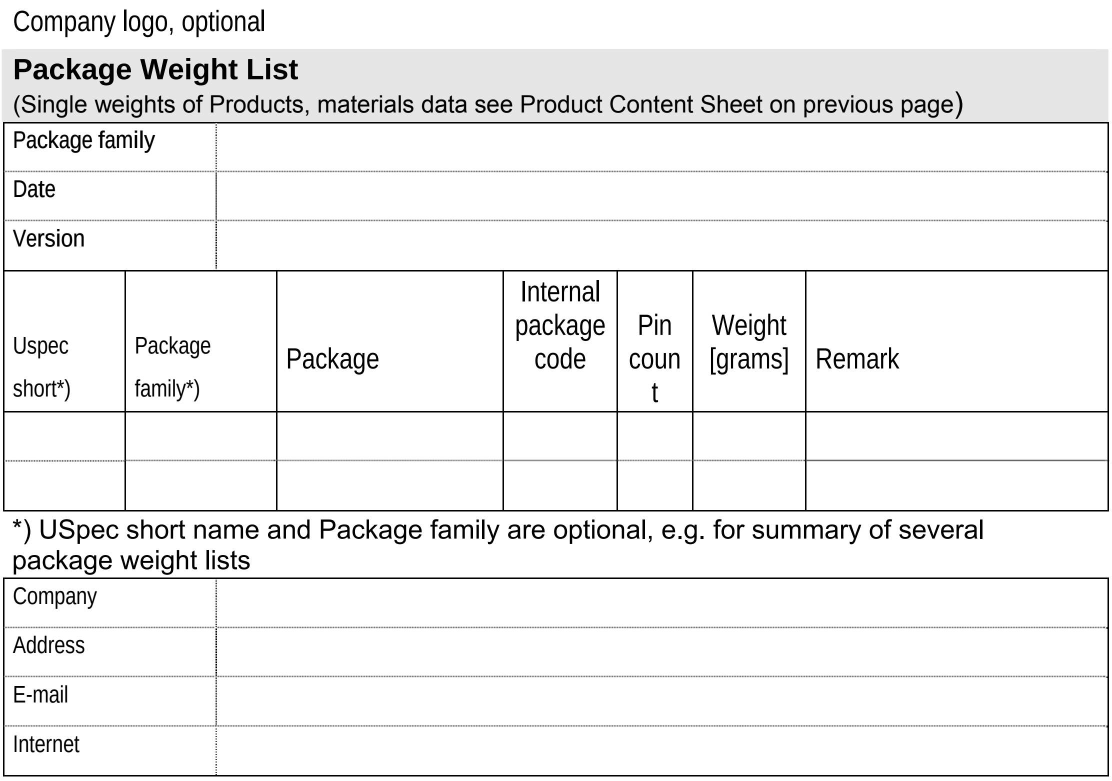
**) optional

Not part of package family	

Company	
Address	
E-mail	
Internet	

Important remarks:

1) Traces are product parts, substances etc. that are below a percentage of 0.1 % by weight. Higher limits are accepted if the substance or material is legally regulated (see note no. 2).
2) A list of the (legal) "... restrictions on substances ..." or materials is available at internet address: http://www.eicta.org/Content/Default.asp?PageID=113.
3) Substances, materials etc. with possible harmful effects on human beings and the environment are listed.
4) There are no risks for human beings and to the environment if products are properly used as designated. This shall not apply to risks caused during procedures for disposal etc.
5) All statements herein are based on our present knowledge. If our products are used properly, there are no risks to human beings and/or the environment.



Company logo, optional

Package Weight List

(Single weights of Products, materials data see Product Content Sheet on previous page)

Package family	
Date	
Version	

Uspec short*)	Package family*)	Package	Internal package code	Pin count	Weight [grams]	Remark

*) USpec short name and Package family are optional, e.g. for summary of several package weight lists

Company	
Address	
E-mail	
Internet	

Figure 1 Basis structure of the Umbrella specifications (http://www.zvei-be.org/materialcontents/doc/USPEC_Form_2.0.doc)

Currently, there are Umbrella specifications available covering the following electrical and electronic components:

Family	**Group**	**Subgroup / Typical Components**
Wire, Cable, Connectors, Cable Assemblies, IC Sockets	Connectors	Connector Metal Housing
		Connector Plastic Housing
Switches, Relays, Electromechanical Components	Fuses and arresters	Surge voltage arrester
Semiconductors, ICs, Transistors, Diodes		56 different types
Capacitors	Electrolytic Capacitors	Speciality Polymer Aluminium Electrolytic Capacitor (SMD)
		Aluminium Electrolytic Capacitor (axial)
		Aluminium Electrolytic Capacitor (radial)
		Aluminium Electrolytic Capacitor (Screw)
		Aluminium Electrolytic Capacitor (SMD)
		Aluminium Electrolytic Capacitor (Snap In)
		Aluminium Electrolytic Capacitor (Snap In - TS type)
	Ceramic Capacitors	Ceramic Capacitor MLCC
	Metallized Film Capacitors	Metallized Film Capacitor (Boxed)
		Metallized Film Capacitor (uncoated)
		Metallized Film Capacitor (Film Chip Capacitor)
	Tantalum Capacitors	Tantalum Capacitor (SMD)
Resistors, Potentiometers, Thermistor NTC	Leaded Resistors	Cemented wirewound
		Cemented wirewound precision
		Low ohmic surge
		Low ohmic
		High ohmic / high voltage
		Professional / Precision
		Fusible
		Professional power metal film
		Radial mounted power film
		Radial mounted power wirewound
		Standard metal film
		Stand-up miniature power film
		Stand-up miniature wirewound
		Ultra precision
	SMD Resistors	SMD Array
		SMD Flat chip
		SMD Thick film flat array
		Thick film flat chip
		MELF
		SMD Power thick film flat chip
	Thermistor NTC	Thermistor NTC (disk)
		Thermistor NTC (SMD)
Printed Circuit Boards, Multilayer, Flexlayer	ZVEI: functional model available	

The contractor analysed the currently available specifications leading to the following results:

- Basically the specifications provide a good basis for the inventory of hazardous substances in EEE.
- However there are data gaps at different levels:
  - There are some components which are not covered by the specifications:

Family	Group
Wire, Cable, Connectors, Cable Assemblies, IC Sockets	Wire
	Cable
Switches, Relays, Electromechanical Components	Switches
	Relays
	Potentiometers
Crystals, Oscillators	
Audioelectronics, Speakers, Microphones	
Electric motors, fans	
Solder	

  - In some cases, the material content is not defined specifically enough to assess the identity of potential hazardous substances.
- According to industry information, the Umbrella specifications are not internationally accepted.

For some of the component families not covered by the specifications other souces could be identified, especially considering electric motors and fans which are covered by the preparatory studies under the EuP directive. For other components, typical values for composition of main materials could be derived from the life cycle inventory database Ecoinvent. However, there is little information about the content of hazardous substances. Therefore assumptions have to be made in order to allocate hazardous substances to the electrical and electronic components (see section 2.6).

2.2.3 XRF analysis

X-ray fluorescence analysis is an established and harmonized method to test electrical and electronic equipment for RoHS compliance. XRF analysis is used by market surveillance authorities as well as companies.

The market surveillance authority of RoHS-directive in Finland (Tukes) was the only organisation making available the test results of electrical and electronic equipment for this study. Tukes supervises the RoHS compliance of electrical and electronic equipment on the Finnish market and provides market surveillance information to the manufacturers, importers and retailers in cooperation with the Ministry of the Environment of Finland (http://www.tukes.fi/en/Toimialat/Electricity-and-lifts/RoHS-directive/).

Tukes measured various parts of electrical and electronic equipment, mostly small household appliances and lighting equipment, by using XRF-equipment. The XRF-method being used provides data on Pb, Hg, Cd, Br and Cr, but on other elements, too (Ag, Au, As, Bi, Ca, Co, Cu, Fe, Mo, Nb, Ni, Sb, Se, Sn, Sr, Ta, Ti, Zn, Zr).

From the small household appliances and lighting equipment, the following components were measured: capacitor/condensers, circuit boards, sensors, lamb holders, wire insulators, solders, glue, plastic parts such as frameplastic, cover plastic (e.g. cover plates bottom plastic, cover of a switch box, cover of a relay), control knobs and plastic from the interior space (referred to as orange, red, etc. plastic), reflector, glass, core of a transformer, connecting wire, etc.

Table 1 summarizes the data for some components of electrical and electronic equipment and for the elements that are listed as top priority substances. The data indicate that the content of the elements in one component greatly varies depending on specific types of the component and probably also manufacturers:

- Depending on the type of wire insulators, the Sb content is or zero or substantial; Cl and Sr content are more or less constant.
- The data for solders vary depending on the electrical and electronic equipment where it was taken from, e.g. from a circuit board.
- Lamp holders show a high content of Cl or of Br; the Br content varies depending on the lamp holders tested.
- As far as plastic parts are concerned, the composition varies, especially the Br content.
- The type of glass determines the Br, Sb, and Pb content.

Table 1 Extract from data of Finnish market surveillance authority Tukes on EEE components from small household appliances and lighting equipment. The measurement was performed by XRF analysis. Results for the elements are indicated as min / max ppm.

Components	**Ni**	**V**	**Co**	**As**	**Cl**	**Br**	**Be**	**Bi**	**Se**	**Sb**	**Sr**	**Pb**
Wire insulators	-	-	-	0 / 25	55,800 / 281,766	-	-	0 / 306	-	0 / 21,700	55 / 140	0 / 59
Circuit board (plastic)	-	-	-	-	-	20,016 / 39,052	-	13 / 67	-	154 / 1,090	-	33 / 49
Circuit board (metal)	0 / 2,642	-	0 / 158	-	-	-	-	-	-	-	491 / 1380	0 / 432
Solder from circuit boards	0 / 63,327	-	190 / 577	-	-	678 / 91,804	-	0 / 21	0 / 1,298	560 / 37,491	0 / 1,107	0 / 495,312
Lamp holder	-	-	-	-	0 / 390,743	0 / 62,551	-	0 / 98	0 / 69	0 / 3,887	0 / 122	0 / 54
Orange plastic	-	-	-	0 / 169	-	21,319 / 32,241	-	26 / 54	17 / 106	0 / 14,713	0 / 50	49 / 261
Frameplastic	0 / 3	-	-	-	-	-	-	-	-	-	0 / 10	-
Cover of relays	-	-	-	-	0 / 52,941	0 / 65,463	-	0 / 71	0 / 22	0 / 21,451	0 / 18	0 / 85
Cage plastic	-	-	-	-	-	0 / 681	-	4 / 5	-	156 / 233	0 / 7	-
Red glass	-	-	-	711 / 183,499	0 / 270,760	0 / 3,682	-	-	-	1,037 / 317,247	39 / 11,916	912 / 358,883
Yellow glass	-	-	-	883 / 1037	-	1 / 2	-	-	-	1,285 / 1,837	21 / 27	61 /75
Components	Ni	V	Co	As	Cl	Br	Be	Bi	Se	Sb	Sr	Pb
Capacitor/condenser (plastic)	-	-	-	-	166,982 / 297,574	-	-	-	-	-	7 / 10	-
Reflector	-	-	-	-	-	-	-	-	-	-	-	-
Core of the transformer	20,059 / 31,650	3,131 / 3,894	17,643 / 35,178	-	-	-	-	-	-	853 / 1,061	0 / 112	-

2.2.4 Literature review

Several existing studies were screened systematically for information on hazardous substances in EEE:

- Andersson, E. (2005): Hazardous substances in electrical and electronic equipment (EEE) – expanding the scope of the RoHS directive; Göteborg University, Sweden & Swedish Chemicals Inspectorate (KemI).
- Brigden, K. & Santillo, D. (2007): Analysis of hazardous substances in a HCL laptop computer; Greenpeace Research Laboratories Technical note 02/07.
- Brigden, K., Webster, J., Labunska, I. & Santillo, D. (2007): Toxic chemicals in computers reloaded; Greenpeace Research Laboratories Technical note 06/07.
- Five Winds International (2001): Toxic and Hazardous Materials in Electronics. An environmental scan of toxic and hazardous materials in IT and telecom products and waste.
- Ogilvie, S.M. (2004): WEEE & Hazardous substances; A report produced for DEFRA, AEA Technology
- etc.

In addition, the Joint Industry Guide (JIG) that specifies material composition declaration for electronic products was used as source of information on hazardous substances that may be present in EEE:

- Joint Industry Guide – JIG (2007): Material Composition Declaration for Electronic Products; JIG-101 A

JIG represents industry-wide consensus on the relevant materials and substances that must be disclosed by suppliers when those materials and substances are present in products and subparts that are incorporated into EEE. The Guide establishes the relevant substances as well as reporting thresholds that the industry agrees should govern material content disclosures. JIG establishes two categories of materials and substances to be declared: (i.e. Level A and B lists. These lists are based on criteria that the industry has determined justify disclosure when these material/substances are present in products or subparts in amounts that exceed their specified threshold levels.

The Level A List is composed of materials and substances that, when used in products and subparts, are subject to currently enacted legislation which

a) prohibits their use;
b) restricts their use; or
c) requires reporting or results in other regulatory effects (e.g. labelling).

The Level B List is composed of materials and substances that the industry has determined relevant for disclosure because they meet one or more of the following criteria:

a) Materials/substances that are of significant environmental, health, or safety interest;
b) Materials/substances that would trigger hazardous waste management requirements;
c) Materials/substances that could have a negative impact on end-of-life management.

The existing Joint Industry Guide is currently being reviewed: As mentioned before, JIG distinguished between Level A and B substances. The criteria for the classification as Level B substance, however, are not well defined in the current version. Therefore, a new version is going to be elaborated that will, according to industry information, only contain one list of declarable substances without distinction of Level A and B substances. This list will comprise substances that are regarded as substances of very high concern (SVHC) according to REACH and that are relevant for electrical & electronic equipment. The Draft JIG Phase 2 Document is scheduled for 2008.

Furthermore, the Guidance Document on the Appliance of Substances under Special Attention in Electric & Electronic Products, published by CEFIC, EECA, EICTA & EUROMETAUX (C4E 2002), as well as manufacturers lists of restricted and banned substances in electrical & electronic equipment were screened for information which substances in EEE are subject of special attention with regard to their possible impact on human health and/or the environment.

- C4E – CEFIC, EECA, EICTA, EUROMETAUX (2002): Guidance document on the appliance of substances under special attention in electric & electronic products. Published in co-operation by CEFIC, EACEM, EECA, EICTA and EUROMETAUX, Version 2.2.
- HP Standard 011 (2007): General Specification for the Environment
- Siemens (2006): Environmentally Compatible Products, Part 2: Hazardous substances, list of prohibited substances, list of substances to be avoided; Siemens Norm SN36350-2.
- Sony Ericsson (2007): The Sony Ericsson Lists of Banned and Restricted Substances.
- Sony (2007): Management regulations for the environment-related substances to be controlled which are included in parts and materials
- etc.

In addition, national regulations (e.g. Norwegian draft regulation on the prohibition of certain hazardous substances in consumer products[7]) as well as the 'List of Chemicals for Priority Action' set up by the OSPAR Commissions[8] and the EU Water Framework Directive[9] have been considered for the establishment of an inventory of hazardous substances in EEE.

2.3 Selection criteria

From the information sources as described in the previous chapter data on a large number of hazardous substances have been gathered. These substances differ broadly regarding their hazardous potential, their existence in EEE and their regulatory status. In order to identify substances which are of high relevance for inclusion into the RoHS Directive, the substances have been characterised according to the following criteria:

1. **Substances of very high concern (SVHC) as defined by REACH.**
   The classification as substances of very high concern is introduced by REACH (use and marketing of these substances can become subject of authorisation under REACH, if the substances are included in the REACH Annex XIV). These substances can cause a high risk to humans and the environment and should be replaced by suitable alternative substances or technologies as soon as possible. The criteria defined in REACH for substances of very high concern refer to three different properties: toxicity, persistence and bioaccumulation. Substances of very high concern are:

   (a) substances meeting the criteria for classification as carcinogenic category 1 or 2 in accordance with Directive 76/548/EE;

   (b) substances meeting the criteria for classification as mutagenic category 1 or 2 in accordance with Directive 76/548/EE;

   (c) substances meeting the criteria for classification as toxic for reproduction category 1 or 2 in accordance with Directive 76/548/EE;

   (d) substances which are persistent, bioaccumulative and toxic in accordance with the criteria set out in Annex XIII of REACH;

   (e) substances which are very persistent and very bioaccumulative in accordance with the criteria set out in Annex XIII of REACH;

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[7] Draft of new chapter concerning consumer products in the Norwegian Product Regulations (http://www.rohs-international.com/site_files/rohs-international.com/Draft_regulations_for_Norwegian_PoHS.pdf)

[8] OSPAR List of Chemicals for Priority Action (Update 2007)

[9] Directive 2000/60/EC of the European Parliament and of the Council (adopted on 23 October 2000) establishing a framework for the Community action in the field of water policy" or, in short, the EU Water Framework Directive (WFD).

(f) substances – such as those having endocrine disrupting properties or those having persistent, bioaccumulative and toxic properties or very persistent and very bioaccumulative properties, which do not fulfil the criteria of points (d) or (e) – for which there is scientific evidence of probable serious effects to human health or the environment which give rise to an equivalent level of concern to those of other substances listed in points (a) to (e) of REACH Article 57.[10]

2. **Substances which have been found as contaminants in humans and biota.**
   These substances not necessarily fulfil the strict criteria for bioaccumulation and persistency as given in Annex XIII of REACH. Nevertheless they have been identified in humans and biota and raise concern regarding potential long-term harmful effects. These properties are at present not expressed by the R-phrases of Directive 67/548, neither are they included in the categories of GHS. The assessment of potential PBT/ vPvB-substances within the EU PBT working group identified a number of substances which raise concern, but which have not been identified as PBT/ vPvB-substances for two reasons: (1) the REACH Annex XIII criteria of persistency and bioaccumulation are very strict. Several substances with a moderate potential for bioaccumulation or with a specific mode of bioaccumulation (which is not covered by the current criteria) did not fulfil the present criteria. (2) Several substances have problematic properties regarding toxicity ***or*** persistency ***or*** bioaccumulation potential. Therefore they could be considered in RoHS, but they do not have the combination of critical properties which is necessary to be characterised as a PBT (which is toxic ***and*** persistent ***and*** bioaccumulative) substance or a vPvB substance (which is very persistent ***and*** very bioaccumulative).
3. **Substances which can form hazardous substances during the collection and treatment of electrical and electronic equipment.**
   A number of substances and materials used in EEE can cause formation of hazardous substances during recycling and/or during incineration. This property is not expressed by the classification of the substances resp. materials themselves. Therefore it is taken as an additional criterion in the selection process.
4. **Substances classified as dangerous according to Annex I Directive 67/548, not fulfilling the REACH criteria for SVHC.**
   A large number of hazardous substances contained in EEE are classified due to their physicochemical hazards (e.g. explosive substances) or due to environmental hazards. Others are classified due to human health hazards, but the effects are not as serious as in the case of substances which are carcinogenic or mutagenic or

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[10] According to REACH these substances have to be identified on a case-by-case basis in accordance with the procedure set out in Article 59 of REACH.

which can damage the reproductive system (CMR substances as characterized under Point 1 above). These substances can cause harm to man and the environment, but are not considered as substances of very high concern.

5. **Substances which are already excluded from electrical and electronic equipment by existing legislation.**
   A large number of hazardous substances have already been regulated by European legislations. It has been checked whether this refers explicitly to the use in EEE (see section 9.5 in the Annex).

Substances with a lower hazardous potential (criterion 4) and substances already excluded by existing legislation (criterion 5) have been documented (section 9.4 and section 9.5 in the Annex), but have not been further evaluated.

Substances which fulfil one of the criteria 1–3 have the potential to cause severe harm to humans and/or the environment. Therefore, they have been given the highest priority in this study. These so-called ***High priority substances*** are listed Table 2.

The substances of Table 2 have been further evaluated. In this context, the exposure situation[11], the relevance of EEE for the total consumption of the substances and the availability of substitutes has been taken into account.

Based on the results of this analysis, a recommendation is made in section 4 on which of the high priority substances of Table 2 constitute significant health and environmental risks due to their use in electrical and electronic equipment. These substances are discussed as ***potential candidates for inclusion into RoHS*** (see section 4).

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[11] If no detailed information on the exposure situation for a substance was available, it has been assumed that exposure of humans and/or the environment by the substance can not be excluded.

2.4 Inventory of hazardous substances and materials in EEE

Based on the information sources described in section 2.2 and applying the selection criteria specified in section 2.3 an inventory of hazardous substances and materials in EEE was established (Table 2). The inventory lists the names and CAS numbers of the hazardous substances, as well as their main use in EEE and their quantities in electrical and electronic components (as far as this information was provided by manufacturers). In addition, the hazard classification according to Annex I to Council Directive 67/548/EEC is included in the inventory as well as the classification as PBT substance and/or endocrine disruptor (ED), if appropriate. It is furthermore indicated whether the hazardous substances fulfil the criteria of substances of very high concern (SVHC) as defined by REACH and whether EU Risk Assessment Report (RAR) are available.

Table 2 Hazardous substances and materials in electrical & electronic equipment

ID	Substance name	CAS-No.	Main use in EEE	Quantity	Hazard classification	REACH SVHC	RAR[12]
1	Tetrabromo bisphenol A (TBBP-A)	79-94-7	Reactive FR in PCB laminates. Additive FR in ABS	40,000 t/a Reactive: 1,000 ppm	N; R50/53[13]	N	Final (HH) Draft (Env) (section 3.1)
2	Hexabromocyclododecane (HBCDD)	25637-99-4	Flame retardant in High Impact Polystyrene (HIPS) e.g. in audio-visual equipment, wire, cables	1-7%	Proposed classification: N R50-53; PBT	Y	Draft (section 3.2)
3	Bis (2-ethylhexyl) phthalate (DEHP)[14]	117-81-7	Plasticiser in PVC cables; Dielectric fluid in capacitors; Encapsulation/potting of electronic		Repr. Cat. 2; R60-61	Y	Draft (section 3.3)

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[12] RAR: EU Risk Assessment Report; HH: Human Health Part; Env.: Environmental Part

[13] TBBP-A is included in the OSPAR List of Chemicals for Priority Action (Update 2007)

ID	Substance name	CAS-No.	Main use in EEE	Quantity	Hazard classification	REACH SVHC	RAR[12]
			components	<0.1%			
4	Butylbenzylphthalate (BBP)[15]	85-68-7	Plasticiser in PVC cables Encapsulation/potting of electronic components	<50%	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	Y	Draft (section 3.3)
5	Dibutylphthalate (DBP)[16]	84-74-2	Plasticiser in PVC cables; Encapsulation/potting of electronics components Silber conductive paint for variable resistors	<5% ~1%	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	Y	Final + Comm. Recomm. (section 3.3)
6	Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	Secondary plasticisers in PVC (cable) flame retardant plasticisers in rubbers Shipping Tube End Cap		Currently not classified according to 67/548; proposed classification: N; R50/53 Endocrine disruptor, Cat 1 (according to EDS database)		Final Env. (section 3.8)
7	Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	Flame retardant in rubber; in industrial and commercial sensors (coin sensors, paper sensors, etc.) where it is found on connector wires of the sensor assembly	Minor use in EEE	Carc. Cat. 3; R40 N; R50-53	Y	Final + Comm. Recomm. (section 3.9)

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[14] DEHP is a Water Framework Directive Priority Substance, and is also subject to a comprehensive risk assessment under Directive 793/93. Risk management proposals are being prepared by the Swedish rapporteur; Restricted for toys by Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC.

[15] Restricted for use in toys by Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

[16] Restricted for use in toys by Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

ID	Substance name	CAS-No.	Main use in EEE	Quantity	Hazard classification	REACH SVHC	RAR[12]
8	Nonylphenol ethoxylates	9016-45-9	Surfactants that can be used in coatings for films in EEE and in formulations to clean printed circuit boards; adhesives	Minor use in EEE adhesives < 2%	Endocrine disruptor, Cat 1 (according to EDS database)	Y	Final + Comm. Recomm. (section 3.10)
9	Diarsenic trioxide; arsenic trioxide[17]	1327-53-3	Fining agent in certain special glasses and glass ceramics, however not clear whether still used for this application; Copper foil in printed circuit boards	<1%	Carc. Cat. 1; R45 T+; R28 C; 34 N; R50-53	Y	-
10	Dinickel trioxide[18]	1314-06-3	Used as colouring agent in certain special glasses. In certain optical / filter glasses + in radiation shielding applications (e.g. welding); Part of ceramics (varistors, NTC)	<1% up to 10 % typically 20 % in NTC, 1% in varistors	Carc. Cat. 1; R49 R43 R53	Y	-
11	Dimethylformamide (DMF)	68-12-2	High voltage/capacity aluminium foil electrolytic capacitors; Power supplies; Printed wiring board epoxy: epoxy hardener material	Minor use in EEE	Repr. Cat. 2; R61 Xn; R20/21 Xi; R36		-
12	Petrolatum	8009-03-8	Used in solder fluxes/pastes; Ceramics (found on the conductive paste used in electrical pattern printing process of the ceramic substrate);		Carc. Cat. 2; R45	Y	-

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[17] Some use restrictions for arsenic compounds by Council Directive 76/769/EEC (item 19 of Annex XVII of REACH)

[18] Restricted in EU by Council Directive 76/769/EEC (item 27 of Annex XVII of REACH) for those applications where nickel is likely to result in direct and prolonged skin exposure

ID	Substance name	CAS-No.	Main use in EEE	Quantity	Hazard classification	REACH SVHC	RAR[12]
			Gaskets of EPDM				
13	Beryllium metal	7440-41-7	CuBe-alloys; NiBe-alloys CuBe alloys are used as conducting spring material in electronic connectors, IC sockets, switches, relays, micro motors Precision co-axial connectors to meet high reliability (xks connects) standard IEEE Std 287-2007 to 110 Ghz. CuBe alloys are used in mobile phones in the following applications: Battery Contact, Speaker Contact, EMI Shield Contact, BtoB Connector, FPC Connector, Antenna Contact, SIM Card Connector, Motor Contact, DC Jack Contact, Microphone Contact CuBe alloys are used in PCs in the following applications: I/O connector, BtoB connector, battery contact, burn-in testing socket, mount socket, PCMCIA connector, optical pickup suspension (CD, MD, DVD); Be metal is used as window on high-resolution x-ray machines	0.2-2 w%	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	Y	- (section 3.11)
14	Beryllium oxide (BeO)	1304-56-9	In ceramics, as cooling device (ceramic insulator); Thermally conductive electrical insulator		Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	Y	- (section 3.11)
15	Antimony trioxide	1309-64-4	Synergist brominated flame retardant Melting agent in special glass, enamel and ceramic manufacture; Fining agent in special glasses;	1-7w% 0.1-1.5%	Carc Cat. 3, Xn, R40	N	Draft (Env/HH) (section 3.12)

ID	Substance name	CAS-No.	Main use in EEE	Quantity	Hazard classification	REACH SVHC	RAR[12]
			Adherence promoter addition in enamel systems Use in varistor ceramics; Used as catalyst in PET film manufacture	100-300ppm			
16	Bisphenol A (4,4'-Isopropylidendiphenol)	80-05-7	Intermediate in polycarbonate and epoxy resin production; Used in the preparation of additive packages for PVC processing; Anti-oxidant in production of plasticisers for use in PVC processing;	Residual BPA in epoxy resins and polycarbonate is low, typically <300 ppm per homogeneous material	Repr. Cat. 3; R62 Xi; R37-41 R43 Endocrine disruptor, Cat 1 (according to EDS database)	Y	Final (section 3.13)
17	Halogenetic organic compounds	-	Various uses e.g. cable insulation, flame retardants, etc		Possible formation of dioxins and furans and other hazardous substances during incineration	N	-

The following figure describes the procedure how the hazardous substances identified in the previous section could be allocated to the most important electrical and electronic components.

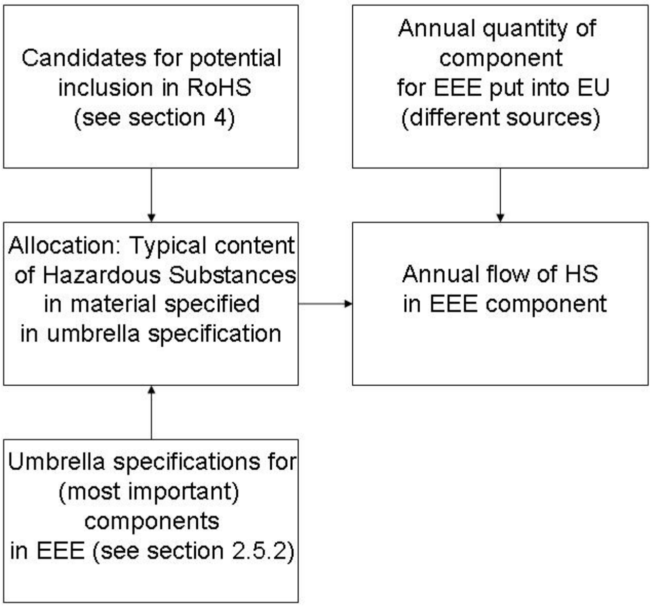


Figure 2 Allocation of hazardous substances to electrical and electronic components

The following table shows exemplarily the allocation procedure for three components. The total database is currently under construction. The draft version will be available for the expert workshop in May 2008.

Table 4 Allocation procedure for three selected components used in EEE

Group	Subgroup / Typical Components	TBBP-A	HBCDD	DEHP, BBP, DBP	PVC (incl. Phthalates)
Connectors	Connector Metal Housing	0,05%	?	?	1,41%
	Connector Plastic Housing	0,44%	?	?	1,00%
Connectors / Cable Assemblies	printer cable, without plugs	?	?	29,17%	72,92%
		....	....	....	....

2.5 Allocation of hazardous substances to EEE products

In a next step the hazardous substances in the previous section were allocated to typical EEE products, where representative bill of materials were available through preparatory studies under the EuP directive. The following figute illustrates the procedure:

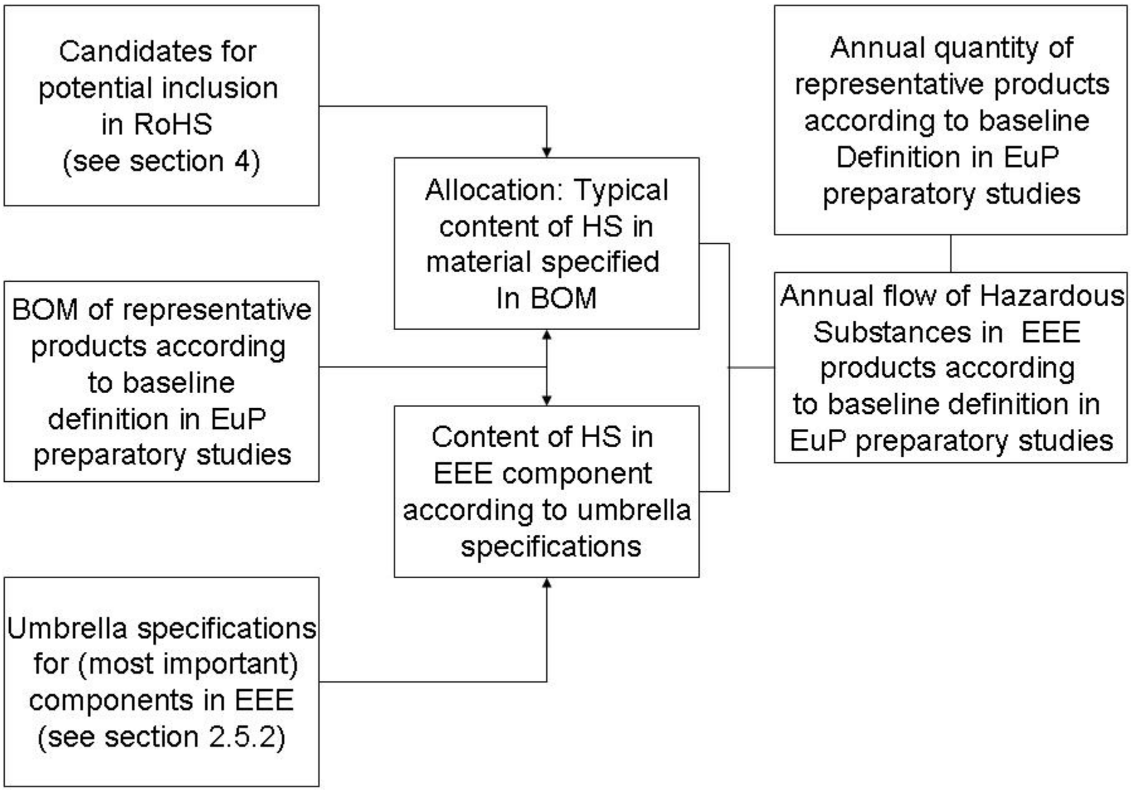
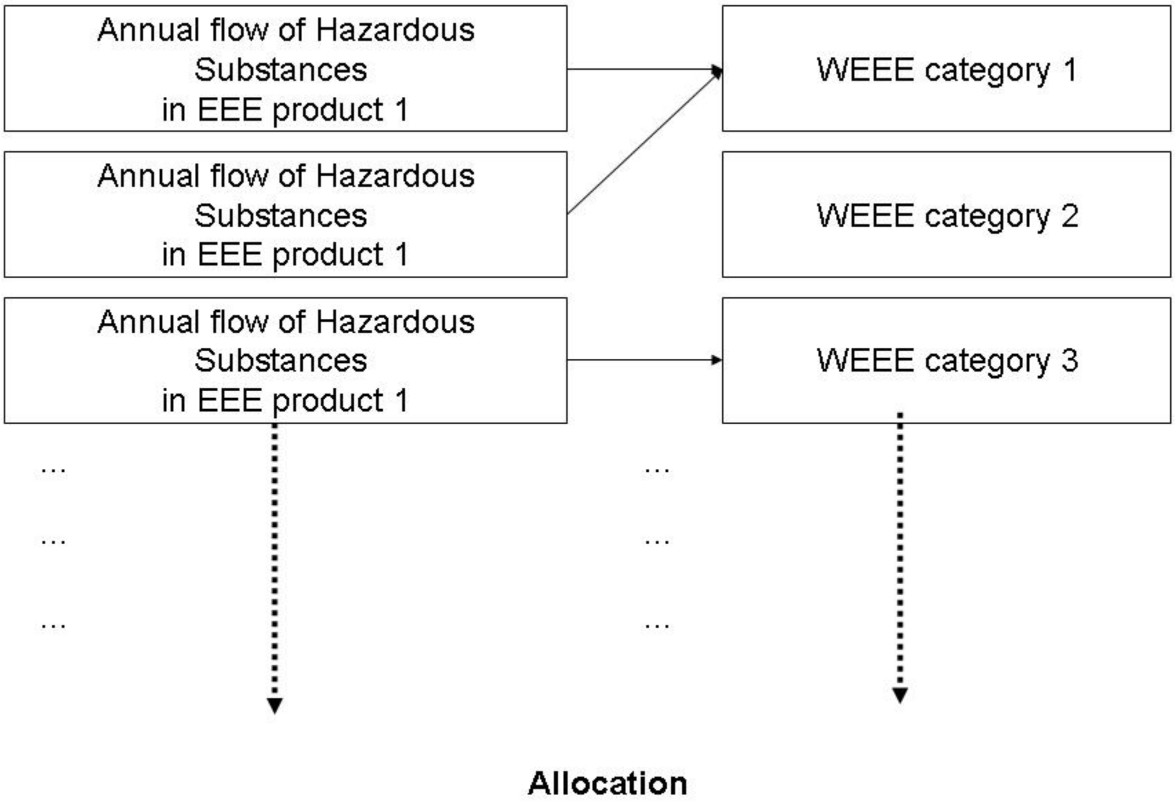


Figure 3 Allocation of hazardous substances to typical EEE products

The database is currently under construction and will be available for the expert workshop in May 2008.

2.6 Allocation of EEE products to WEEE categories

In the last step, the selected products were allocated to WEEE categories, thus giving evidence about the percentage of the particular annual quantities. The following figute illustrates the procedure:



However, this level of inventory can only be completed systematically for those products, where representative data are available based on the ongoing preparatory studies under the EuP Directive, see the table below.

Table 3 WEEE categories, typical products, and assignment of products with existing BOM (Bill of materials).

WEEE Category #	**(WEEE) category title**	**Products**	**BOM of products available (EuP preparatory studies)**
1	Large household appliances	large cooling appliances; refrigerators; freezers; other large appliances used for refrigeration, conservation and storage of food; washing machines; clothes dryers; dish washing machines; cooking; electric stoves; electric hot plates; microwaves; other l	washing machines; dish washer; boilers; water heater; electric motors; refrigerators; refrigerator-freezer; upright freezer;
2	Small household appliances	vacuum cleaners; carpet sweepers; other appliances for cleaning; appliances used for sewing, knitting, weaving and other processing for textiles; irons and other appliances for ironing, mangling and other care of clothing; toasters; fryers; grinders, coff	external power supplies; (vacuum cleaners)
3	IT and telecommunications equipment	centralised data processing; mainframes; minicomputers; printer units; personal computing; personal computers, including	Desktop PC; Laptop; LCD display; CRT display; EP-Copier/MFD and SFD,

		the CPU, mouse and keyboard; laptop computers, including the CPU, mouse and keyboard; notebook computers; notepad computers; printers;	monochrome and colour; IJ-Printer/MFD Personal and Workgroup; External Power Supplies;
4	Consumer equipment	radio sets; television sets; video cameras; video recorders; hi-fi recorders; audio amplifiers; musical instruments; other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the d	32" LCD-TV; 42"PDP-TV; 29"CRT-TV; External Power Supplies;
5	Lighting equipment	luminaires for fluorescent lamps; straight fluorescent lamps; compact fluorescent lamps; high intensity discharge lamps, including pressure sodium lamps and metal halide lamps; low pressure sodium lamps; other lighting equipment for the purpose of spreadi	External Power Supplies; Fluorescent lamps; Electromagnetic gear; Electronic ballasts; Luminaires
6	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	drills; saws; sewing machines; equipment for turning, milling, sanding, grinding, sawing; cutting; shearing; drilling; making holes; punching; folding; bending or similar processing of wood, metal and other materials; tools for riveting, nailing or screwi	External Power Supplies;
7	Toys, leisure and sports equipment	electric trains or car racing sets; hand-held video game consoles; video games; computers for biking, diving, running, rowing, etc.; sports equipment with electric or electronic components; coin slot machines	External Power Supplies;
8	Medical devices (with the exception of all implanted and infected products)		
9	Monitoring and control instruments		
10	Automatic dispensers	automatic dispensers for hot drinks; automatic dispensers for hot or cold bottles or cans; automatic dispensers for solid products; automatic dispensers for money; all appliances which deliver automatically all kind of products	
-	Electric light bulbs and luminaires in households		Fluorescent lamps; electromagnetic gear; electronic ballasts; luminaires

The database is currently under construction and will be available for the expert workshop in May 2008.

2.7 Collection and treatment of electrical and electronic equipment within EU

In the discussion on disposal/recycling of products containing hazardous substances it is often argued that disposal (e.g. dismantling, shredding, incineration, etc.) and recycling of EEE take place in high-standard incineration / recycling plants and non-recyclable waste ends up in sealed landfills. These controlled disposal and recycling conditions are considered as risk management measures reducing the environmental and human exposure to hazardous substances. Investigations in the current practice of collection and treatment of waste electrical and electronic equipment indicate, however, that a large portion of EEE waste is not disposed of and/or recycled within the EU. A large but is shipped to non-EU countries.

In the EU27, the collection and treatment of waste electrical and electronic equipment is regulated by Directive 2002/96/EC on waste electrical and electronic equipment (WEEE-Directive). Amongst others, the Directive sets quantitative collection, recycling and recovery targets for the different product types and defines the framework for establishing a European wide collection system, including its organisation and financing by the manufacturers of such equipment. Inter alia, the Directive targets to collect 4 kg of WEEE per capita from private households annually. No collection target is given for non-household WEEE.

In August 2007, an extensive review of the Directive was published, giving insights into the strengths and weaknesses of the practical implementation (Huismann et al. 2007). Amongst others, the study elaborated on the current collection rates of the different WEEE-types arising. It turned out that for most WEEE-types collection is still well below 50% (see Table 4), which means that the currently installed collection system and treatment is only partly able to manage the European WEEE-volume.

Table 4 Current amount of WEEE collected and treated as percentage of WEEE arising (Source: Huismann et al. 2007).

#	Treatment category	Current % collected of WEEE arising
1A	Large Household Appliances	16.3%
1B	Cooling and freezing	27.3%
1C	Large Household Appliances (smaller items)	40.0%
2, 5A, 8	Small Household Appliances, Lighting equipment – Luminaires and ‘domestic’ Medical devices	26.6%
3A	IT and Telecom excl. CRTs	27.8%
3B	CRT (Cathode Ray Tube) monitors	35.3%
3C	LCD (Liquid Crystal Display) monitors	40.5%
4A	Consumer Electronics excl. CRTs	40.1%
4B	CRT TVs	29.9%
4C	Flat Panel TVs	40.5%
5B	Lighting equipment – Lamps	27.9%
6	Electrical and electronic tools	20.8%

#	Treatment category	Current % collected of WEEE arising
7	Toys, leisure and sports equipment	24.3%
8	Medical devices	49.7%
9	Monitoring and control instruments	65.2%
10	Automatic dispensers	59.4%

Although there are no reliable figures on the whereabouts of WEEE not collected, there are only three possibilities: A) WEEE is stored in private households for longer periods; B) WEEE is disposed via municipal waste stream or via any other inappropriate way; C) WEEE is refurbished and/or reused (extension of use-phase) in- or outside the EU.

While from an end-of-life perspective option A only causes a time lag of the de-facto end-of-life phase, option B in any case has significant environmental impacts. The impacts of option C largely depend on the geographic location of reuse: If the devices are reused within the EU, they are still covered by the WEEE-Directive, and it depends upon the user to bring them to a municipal collection point once obsolete. If the devices are refurbished and/or reused in non-European countries, it is very unlikely that the recycling and disposal will be carried out in an environmentally sound manner.

Option B: Disposal via municipal waste stream

A survey from Cardiff, Great Britain revealed that 26% of all small electrical and electronic equipment are disposed of via the household refuse (Darby & Obara, 2005). Since the study considers products up to the size of radios and laptop computers, this finding addresses a large range of electric and electronic equipment. Although this figure cannot be extrapolated to other EU member states, it can be presumed that – for convenience reasons – a significant share of the smaller WEEE fractions end up in the treatment systems for household waste. Depending on the national waste treatment systems, this will lead to landfill or incineration without adequate off-gas treatment.

Option C: Refurbishment and reuse

There is strong evidence that significant amounts of used and obsolete electrical and electronic equipment are shipped for refurbishment and reuse to African and Asian destinations. A survey carried out in the harbour of Hamburg in 2007 revealed that large amounts of used equipment is exported to West-Africa, Egypt, China, Malaysia and other developing countries (Buchert et al. 2007). Although there are no quantitative figures available, there are interview statements that claim that every month 500 containers filled with used EEE are shipped from Hamburg to Lagos. In addition, many used cars and trucks dedicated for West-Africa are filled with goods like used EEE before boarding. Furthermore, there is evidence for more organised large-scale exports to Asia, especially for CRTs. So far, only Hamburg has been covered by such export studies and it can be presumed that used EEE is also shipped from some other European ports.

Although the sources of these streams of used equipment are largely unknown, there are at least some specialised trading agencies that purchase used ICT-equipment directly from companies (Buchert et al. 2007). Furthermore, an unknown volume of used equipment is diverged from the official WEEE collection and treatment systems (Huismann et al. 2007). An additional source of exports of used EEE are charity organisations that send donated equipment (especially computers) to developing countries to help bridge the 'digital divide' (Osibanjo & Nnorom 2007).

A wide range of studies could document the recycling and disposal practices in Asian and African EEE destinations: In China and India, EEE not suitable for refurbishment undergoes so called 'backyard recycling' with the aim to recover plastics, copper, silver and gold with comparably low yields. These recycling practices and the subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards (e.g. open burning of copper wires, treatment of PCBs in open acid baths, cyanide leaching to recover gold). The residues are mostly disposed uncontrolled (Hicks et al. 2005, Manhart 2007, Osibanjo & Nnorom 2007). In African WEEE recycling, the primary aim is to recover copper. The residues are disposed on uncontrolled dump sites, which are set on fire regularly (Puckett et al. 2005).

2.7.1 References

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3 Characterisation of hazardous substances

Substances which fulfil one of the criteria 1–3 defined in section 2.3 have the potential to cause severe harm to humans and/or the environment. Therefore, they have been given the highest priority in this study. These so-called "high priority substances", listed in Table 2, have been further evaluated. In the following section the high priority substances are characterised and discussed (as far as information is available) with regard to

- their use in EEE;
- the legislations under which the substances are currently managed;
- their classification: Annex I of Council Directive 67/548/EEC; CMR; PBT / vPvB; SVHC;
- the risk for the environment and human health arising from the use of the hazardous substances in the different life stages of EEE.

Based on the results of this analysis, a recommendation is made in section 4 which of the high priority substances of Table 2 constitute significant health and environmental risks due to their use in electrical and electronic equipment. These substances are discussed as "potential candidates for inclusion into RoHS" (see section 4).

The data and information presented in this chapter derive in a large part from available EU Risk Assessment Reports (RAR) published by the European Chemicals Bureau (ECB)[19].

With regard to the EU Risk Assessment Reports, several national authorities emphasise that for substances of very high concern the current risk assessment procedure does not meet the requirements for a sustainable policy and does not take the precautionary principle into account. According to the approach of the EU chemical evaluation process even substances of very high concern (e.g. cancerogenic, mutagenic, reprotoxic, PBT, vPvB substances or endocrine disruptors) will only pose a risk to environment and human health if expected environmental concentrations and predicted exposure of humans exceed the predicted no-effect concentrations. Some Member States, however, support the position that because of the precautionary principle substances of very high concern should not be released into the environment at all.

According to REACH, for substances of very high concern it is required to assure that the risks from these substances are properly controlled and that these substances are

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[19] http://ecb.jrc.it/esis/index.php?PGM=ora

progressively replaced by suitable alternative substances or technologies where these are economically and technically viable (REACH Article 55). For persistent, bioaccumulative, and toxic substances (PBT), and for very persistent and very bioaccumulative substances (vPvB), a specific assessment of the hazardous properties and the exposure has to be made as part of the chemical safety report.

Experience with PBT/vPvB-substances has shown that they give rise to specific concern due to their potential to accumulate in parts of the environment. The effects of such an accumulation are unpredictable in the long-term. In addition, such an accumulation is practically difficult to reverse as cessation of emission will not necessarily result in a reduction in chemical concentration.

These properties of PBT/vPvB substances lead to an increased uncertainty in the estimation of risk to human health and the environment when applying quantitative risk assessment methodologies. For PBT- and vPvB substances a “safe” concentration in the environment cannot be established using the methodology currently available with sufficient reliability for an acceptable risk determined in a quantitative way. Similar to the situation for PBT-substances and vPvB-substances, a “safe” concentration without risk can also not be obtained for substances of chronic toxicity which exert its effects by a non-threshold mode of action.

In order to reduce the exposure of humans and the environment to these substances as far as possible, substances of very high concern should be replaced by less hazardous substances wherever it is possible.

3.1 Tetrabromobisphenol-A (TBBP-A)

3.1.1 Use

TBBP-A is a brominated flame retardant (FR) used in EEE. Currently, TBBP-A is the most widely used brominated flame retardant and is produced in the largest volume. The primary use of TBBP-A is as a reactive flame retardant in printed circuit boards (PCB). It is also used as an additive flame retardant in polymeric material in housings and packaging.

The total European consumption of TBBP-A assumed from the demand for EEE (around 1/3 of the world-wide total) can be estimated at around 40,000 tonnes/year. Thereof, 13,800 tonnes/year are imported into the EU as the substance itself, 6,000 tonnes/year are estimated for partly finished products (e.g. masterbatch, epoxy resins) and 20,200 tonnes/year for finished products and components.

Reactive flame retardant

TBBP-A is primarily used as an intermediate in the manufacture of flame-retarded epoxy and polycarbonate resins. When used as an intermediate it is covalently bound in the polymer and becomes a constituent of the base material. Bleeding out of the molecule or vaporising is therefore prevented. Free residual monomer is likely to be less than 200 ppm (or < 0.02% by weight). If TBBP-A is added excessively, unreacted TBBP-A may exist. Commercial flame retardant epoxy resins contain up to approximately 20% bromine which is equivalent to a TBBP-A content reacted in the polymer backbone of around 34%.

The use of TBBP-A as reactive flame retardant accounts for approximately 90% of the use of TBBP-A as flame retardant (ca. 5,850 tonnes/year). The two main applications are:

- Epoxy resins in printed circuit boards: rigid or reinforced laminated printed circuit boards most commonly based on glass fibre reinforced epoxy resin (designated FR4-type) is typically used in computers and telecommunications equipment. Especially in the high-priced market segment, the FR4-type laminates is used in television sets, computer equipment etc.
- Epoxy resins to encapsule certain electronic components: e.g. plastic/paper capacitors, microprocessors, bipolar power transistors, IGBT (Integrated Gate Bipolar Transistor) power modules, ASICs (Application Specific Integrated Circuits) and metal oxide varistors) on the printed circuit board.

TBBP-A is also used as a reactive flame retardant in polycarbonate and unsaturated polyester resins:

- Polycarbonate polyester resins are used in communication and electronics equipment and electronic appliances.
- Unsaturated polyesters resins are usually used in a wide range of non-EEE applications, but also for encapsulating electrical devices.

Additive flame retardant

As an additive flame retardant TBBP-A, is added to polymers to impart flame retardant properties. It does not react chemically with the other components of the polymer, and, therefore may leach out of the polymer matrix. Additive use accounts for approximately 10% of TBBP-A used or 650 tonnes/year. Its main use as an additive flame retardant is in acrylonitrile-butadiene-styrene (ABS) resins.

The main applications where plastic containing TBBP-A are used are TV-set back casings. Other uses include printed circuit boards, PC monitoring casings, components in printers, fax machines and photocopiers, vacuum cleaners, coffee machines and plugs/sockets. For example:

- Acrylonitrile-butadiene-styrene (ABS) resins are used in refrigerators, other appliances, business machines, and telephones.
- Printed circuit boards based on cellulose paper with reinforced phenolic resin are mainly used in low energy applications such as remote controllers for televisions, video recorders etc.

Where TBBP-A is used as an additive flame retardant, it is generally used with antimony trioxide as a synergistic system for maximum performance.

3.1.2 Current legislation

- At present no occupational exposure limits for TBBP-A are established in Europe.
- TBBP-A is included in the OSPAR List of Chemicals for Priority Action (Update 2007).
- Indirectly, the regulations on the design of municipal incinerators include provisions for TBBP-A containing materials. Therein, a minimum incineration temperature of 850°C for 2 seconds is required (EEC 1989a and 1989b). A higher incineration temperature of 1,100°C is required for hazardous waste incinerators where waste containing more than 1% halogens is incinerated (EEC 1994). At high temperatures (e.g. around 800°C) only trace amounts of mainly mono- and dibrominated dibenzo-p-dioxins and dibenzofurans appear to be formed from TBBP-A containing materials.
- Some national regulations cover the management of waste from electrical and electronic products or incineration in general:
  - In Denmark, flame-retarded plastic has to be separated out from other waste from electrical and electronic equipment and this plastic has to be recycled, incinerated or deposited at approved facilities. In the case of recycling, the plastic has to be used for products for which special requirements apply for fire safety reasons, according to the Ministry of Environment and Energy’s Statutory Order No. 1067 of 22 December 1998.
  - In the United Kingdom, incineration processes should meet an emission standard for chlorinated dioxins of 1.0 ng TEQ/m3 (Environmental Protection Act 1990). Given the similarities between chlorinated and brominated dioxins and the mechanism of their formation, incinerator design and abatement technologies employed for chlorinated dioxins and furans should also be effective in limiting the emissions from the brominated analogues.

- Norway proposes a prohibition of TBBP-A as additive flame retardant in consumer products with more than 1% TBBP-A by weight in the product's homogeneous components parts. [20]
- On European level TBBP-A has been proposed by the European Parliament to be included in the list of priority substance of the Water Framework Directive.

The European brominated flame retardant industry has included TBBP-A in the VECAP programme. VECAP stands for **V**oluntary **E**missions **C**ontrol **A**ction **P**rogramme. It was set up to manage, monitor and minimise industrial emissions of brominated flame retardants into the environment through partnership with the supply chain including Small and Medium-sized Enterprises (SMEs).

3.1.3 Classification

TBBP-A is not currently classified for environmental or human health effects.

The proposed classification for the environment is:

Environment	N; R50/53: - Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Endocrine disruption

There are indications of potential effects on the endocrine system in some *in vitro* tests with aquatic organisms. However, these effects could not be confirmed by *in vivo* studies. For mammalian systems, the human health assessment concludes that the weight of evidence from in vitro screening in assays indicates that TBBP-A has no significant estrogenic potential in mammalian systems. It should, however, be noted that the effects of TBBP-A on the endocrine system are subject to current research (e.g. in the EU FIRE project[21]). The FIRE project (Flame retardants Integrated Risk assessment for Endocrine effects) supported by the European Commission investigates the possible emerging health risk for humans and wildlife of brominated flame retardants (BFRs) including TBBP-A by endocrine related mechanisms. Final results of this study are not yet available.

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[20] Norway proposes prohibition of certain hazardous substances in consumer products (SFT 2007a & SFT 2007b)

[21] FIRE (Flame retardants Integrated Risk assessment for Endocrine effects): Risk Assessment of Brominated Flame Retardants as Suspected Endocrine Disrupters for Human and Wildlife Health

PBT and vPvB evaluation

TBBP-A is considered to be persistent (P) or potentially very persistent (vP) based on its ultimate mineralisation. The available information on bioaccumulation shows that TBBP-A does not meet the B or vB criterion. The highest measured bioconcentration factor (BCF) value for fish is 1,234 l/kg. This value is below the cut-off value of 2,000. However, it should be noted that the available monitoring data suggest that the substance is present at low levels in the tissues of a wide variety of marine organisms including some top predators, predatory birds from remote areas (e.g. northern and arctic regions of Norway) and human breast milk from remote areas (e.g. the Faro Islands). The T criterion is not met.

Some Member States concluded that TBBP-A is considered to be very persistent (vP).

SVHC

TBBP-A does not fulfil the criteria for substances of very high concern (SVHC) as defined by REACH.

3.1.4 Risk assessment

Environment

Exposure

Releases to the environment will occur over the whole life-cycle as a result of the processing, use and disposal of TBBP-A and plastics containing TBBP-A.

Specific release information for TBBP-A are not available for many stages of the life-cycle and thus the emission estimation and risk assessment was partly conducted on the basis of default emission factors. This procedure is considered as one area of uncertainty in the environmental risk assessment (ECB 2007).

The total amount of TBBP-A that is estimated to be present (either as an additive or reacted into the polymer backbone) in new products in the EU is approximately 40,000 tonnes/year. About 90% of the TBBP-A in finished products is used in reactive applications and 10% is used in additive applications. Thus the amount of TBBP-A present as an additive in finished products is 4,000 tonnes/year. For the reactive use, TBBP-A can only be released from the product if it is present as residual monomer. It is assumed that a maximum of 0.06% of the TBBP-A used as a reactive flame retardant is available as residual monomer and not bound into the polymer backbone. Thus, the maximum amount of residual monomer present in finished articles where TBBP-A is used as a reactive flame retardant would be 21.6 tonnes/year.

TBBP-A may be released from EEE by leaching or volatilisation over the lifetime of the products. This is particularly the case when TBBP-A is used as an additive flame retardant, but is also possible if when used as a reactive flame retardant it is not completely reacted into the polymer backbone.

With regard to leaching loss during the use of EEE it is concluded that the amount leached from the products over their use lifetime will be very low because EEE are unlikely to come into contact with water. This applies both for reactive and additive flame retardant applications.

The potential for volatilisation of TBBP-A from plastics where it is used as a reactive flame retardant is considered to be very low. The reason for this is that the vast majority of the TBBP-A used is reacted into the polymer matrix and so is not available for release through volatilisation. However, any TBBP-A present as residual monomer could be volatilised from the polymer over extended time periods. The daily emission of TBBP-A from a computer monitor containing additive TBBP-A in a typical office was estimated to be ca. 0.61 µg/day resulting in an approximate daily emission factor of 2.2 µg/kg TBBP-A.

In order to estimate releases during recycling and disposal it is distinguished between (a) the collection, separation and shredding/regrinding of plastic containing TBBP-A and (b) the remelting and reshaping of the collected plastic: epoxy resins used in printed circuit boards containing reactive TBBP-A cannot be remelted and so are not normally recycled. The potential for emissions of TBBP-A from the collection, separation and regrinding of printed circuit boards would appear to be limited owing to the relatively low residual or free TBBP-A content of the polymer.

Recycling of plastics containing additive flame retardants is not routinely carried out in the EU. Emission of TBBP-A during collection, separation and shredding/regrinding of plastics containing additive TBBP-A may result in predicted concentrations in the air of up to 0.75 µg/m³.

The plastics containing TBBP-A will usually be disposed of either to landfill or by incineration. When plastic containing TBBP-A, either as an additive or as residual monomer, is disposed of to landfill, in theory it could volatilise to the atmosphere or leach out of the plastic into groundwater. It is not currently possible to quantify the actual releases of TBBP-A from landfills. Such releases have been shown to occur, however they are generally expected to be low.

It is expected that the emissions of TBBP-A from incineration processes will be near zero. However, an area of potential concern for both direct toxicity and secondary poisoning is the possible formation of brominated dibenzo-p-dioxins and dibenzofurans from articles containing TBBP-A during combustion or other high temperature processes (e.g. incineration, landfill – where fires could occur – or accidental fires). It can be concluded that TBBP-A, as a source of bromine, can contribute to the formation of halogenated dibenzo-p-dioxins and dibenzofurans generated during such processes.

Risk characterisation

Based on the available model calculations, risks may arise for the environmental compartments water, sediment and agricultural soil by the use of TBBP-A as additive flame retardant in ABS. No risks were identified for the use of TBBP-A as reactive flame retardant in the manufacture and processing of epoxy and polycarbonate resins.

TBBP-A may be degraded to a number of degradation products (metabolites). These include bisphenol-A and TBBP-A bis(methyl ether). Bisphenol-A is currently also undergoing a risk assessment under the Existing Substances Regulation. Bisphenol-A is toxic (T) and has endocrine disrupting properties (please refer to section 3.13.3). The tentative PBT assessment of TBBP-A bis(methyl ether) reaches the conclusion that this substance is persistent or even very persistent (P or vP) and bioaccumulative or even very bioaccumulative (B or vB).

Monitoring

Available monitoring data show that TBBP-A was found in samples taken in remote areas: TBBP-A has been detected in human breast milk from the Faroe Islands. Furthermore, TBBP-A was present in samples of predatory birds' eggs from Norway (including some sampled from within the arctic circle). Monitoring data in aquatic organisms show that TBBP-A has been detected at low levels in a number of aquatic species, including some top predators such as harbour porpoise.

Human health

Occupational Exposure

Possible exposure may occur by inhalation and dermal exposure. High personal exposure by inhalation may be found during the addition of TBBP-A powder to batches of plastics to produce a masterbatch. Other potential inhalation exposures to TBBP-A (e.g. during computer recycling or printed circuit board assembly) are small and in the case of office workers very low. Dermal exposure is assumed to be negligible for all applications of TBBP-A. As for inhalation, there are measured data, but no data for personal exposure.

Consumer exposure

Consumer exposure to TBBP-A is likely to be insignificant. Consumer exposure can occur by inhaling, ingesting or by contact with dust containing TBBP-A or inhaling TBBP-A vapour or dust from hot consumer equipment like TVs or computers. For this to happen, dust from the polymer matrix has to become available for inhalation or ingestion or (dermal) contact or has to leach from the polymer as free, unreacted TBBP-A. The potential for volatilisation of TBBP-A is small, especially under room temperature. Also, in cases where TBBP-A is incorporated in an additive form, emissions of TBBP-A from e.g. computer monitor housings, where the flame retardant was present in an additive form, were negligible.

Indirect exposure via the environment

There are findings of TBBP-A in human blood-samples and samples of human breast milk that show that population exposure to TBBP-A can be reflected in increased internal levels of the substance. However, it is not possible to point out specific sources to the TBBP-A exposure.

Accidental fire

During accidental fire, the release of brominated dibenzo-p-dioxins and dibenzofurans from plastics containing TBBP-A, which occurs under certain pyrolysis conditions, is a possible environmental concern. Generally, the amounts of these products formed from TBBP-A appear to be less than from some other brominated flame retardants such as the polybrominated diphenyl ethers.

Risk characterisation

The hazardous properties of TBBP-A have been evaluated to the extent that the minimum data requirements according to Article 9(2) of Regulation 793/93 have been met. Overall, with the exception of potential nephrotoxicity for infants, no other health effects of concern have been identified. As no health effects of potential concern to adults have been identified, no risk characterisation for workers, consumers or for the indirect exposure via the environment has been performed. A risk assessment on the exposure of infants via breast milk resulted in the conclusion that there is at present no need for further information and/or testing and for risk reduction measures beyond those which are being applied already.

3.1.5 Disposal and recycling

The data presented in the EU RAR originate from the time before the WEEE Directive became effective. According to this situation, the vast majority of EEE are disposed of to landfills or – to a smaller extent – incinerated.

Landfill or any other form of disposal bears the possibility that articles containing TBBP-A mixed with other waste prior or during disposal contribute to the formation of hazardous products (e.g. halogenated dibenzo-p-dioxins and furans). But this potential is unlikely unless a landfill fire occurs.

Incineration

The release of brominated dibenzo-p-dioxins and dibenzofurans from incineration of plastics containing TBBP-A involving articles containing TBBP-A is of possible environmental concern. Factors that appear to affect the formation include the temperature and the residence time at the temperature. At high temperatures (e.g. around 800°C) only trace amounts of mainly mono- and dibrominated dibenzo-p-dioxins and dibenzofurans appear to be formed.

Recycling

According to the information provided in the EU RAR most specialist recyclers for computers and electronic equipment usually dismantle manually. The plastic housings are land filled or incinerated. Only internal parts of the electrical and electronic equipment are partly recycled, especially the copper from the printed circuit boards. This metal recycling involves very high temperatures. Thus, there is potential for formation of dibenzo-p-dioxins and furans if TBBBP-A containing material enters the recycling process. The relevance of TBBP-A is estimated to be low since it is not the only possible source of halogens.

Epoxy resins used in the printed circuit boards cannot be recycled by remelting. Only particle downcycling and re-use of epoxy resins is possible. This is done on a limited scale in Germany. Waste from laminate and printed circuit board are grinded and separated into metal and plastic fractions. The plastic fraction can be used as a supplement or filler in other products made from flame-retarded thermosetting resins. Thermoplastics (e.g. PEI – polyetherimid, PES – polyethersulfon) can theoretically be remelted and reformed.

Overall, the release of TBBP-A from electrical and electronic equipment during use and/or waste disposal is not sufficiently considered in the EU RAR.

3.1.6 References

- EU Risk Assessment Report 2,2’,6,6’-Tetrabromo-4,4’-Isopropylidene Diphenol (Tetra-bromobisphenol-A), Final Environmental Draft (2007).
- EU Risk Assessment Report 2,2’,6,6’-Tetrabromo-4,4’-Isopropylidenediphenol (Tetra-bromobisphenol-A or TBBP-A), Part II – Human Health, Final Report (2006).
- OSPAR Commission (2007): OSPAR List of Chemicals for Priority Action (Update 2007); OSPAR Convention for the Protection of the marine environment of the North-East Atlantic; Reference number 2004-12.

3.2 Hexabromocyclododecane (HBCDD)

3.2.1 Use

HBCDD is a brominated flame retardant mainly used in the polymer and textile industries. The primary use of HBCDD is in polystyrene that is applied to rigid insulation panels and boards for building construction. About 2% of HBCDD are used in high impact polystyrenes (HIPS) mostly used in EEE which include, for example, audio visual equipment cabinets, distribution boxes for electrical lines in the construction sector and refrigerator lining. HBCDD is an additive flame retardant with concentrations of 1-7% in HIPS (KEMI 2006).

The industrial use of HBCDD amounts to approximately 9600 tonnes/year. The EEE relevant use of HIPS contributes with more than 210 tonnes/year. In addition, HBCDD is likely to be imported to the EU in EEE as end-products, but data are not available.

HIPS are produced either in a batch or continuous polymerisation process. HBCDD is added as part of different flame retardants. HBCDD and other ingredients required for the particular HIPS are metered in the extruder for further mixing, homogenization and granulation into pellets.

3.2.2 Current legislation

- The EU directive 2002/96/EG on Waste Electrical and Electronic Equipment regulates the separation of all plastic scrap if it contains brominated flame retardants.
- At present no occupational exposure limit values for HBCDD are established in Europe.
- Occupational exposure limit values for organic dust and mist which are in Sweden 5 mg/m³ and many other countries 10mg/m³ may be applied to HBCDD, according to the EU RAR.
- Norway plans a prohibition for HBCDD in consumer products within 2008.
- In September 2007, Sweden has submitted proposals to reduce the risk of HBCDD by constraining almost all uses of HBCDD (KEMI 2007, inedited).
- The EU scientific risk assessment according to (EC) Regulation 793/93 is yet to be finalised.

3.2.3 Classification

Hexabromocyclododecane is currently not included in Annex I to Directive 67/548/EEC. The proposed classification is:

Environment	N; R50/53: - Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment

Endocrine disruption

According to some in vitro and in vivo tests, impacts on the endocrine system by HBCDD are not found to a major extent. In aquatic organisms limited potential for in vivo endocrine disruption of the reproductive and thyroid hormonal system in immature flounder is detected. The potential of endocrine effects still needs to be examined and validated which is currently done by the EU project FIRE.

PBT and vPvB evaluation

Hexabromocyclododecane seems to be fairly persistent (P) in aerobic soil. The half-lives of the individual diastereomers were approx. 210, 130 and 200 days for α-, β-and γ-HBCDD, respectively when temperature-corrected to 12°C. No firm conclusion can be drawn from the performed simulation degradation studies regarding whether or not HBCDD fulfils the P-criterion for sediment. Based on data of high bioaccumulation factors it is shown that HBCDD meets the vB criterion. A study on fathead minnow gave a steady state BVCF of 18100 after 32 days exposure. The T criterion is fulfilled. Although HBCDD does not unequivocally fulfill all the P-criterion, however, it bioaccumulates significantly, is a toxic substance and can be found in marine biota distant from anthropogenic. The current draft conclusion of the RAR says:”although HBCDD does not unequivocally fulfil all the individual criteria (P-criterion), it is concluded that the substance **overall** fulfils the PBT-criteria of the current chemical policies.”

SVHC

Due to the fact that HBCDD fulfils the PBT-criteria, it is a substance of very high concern.

3.2.4 Risk assessment

Environment

Exposure

The EU RAR entails predominantly emission release information for the major uses of HBCDD based on site-specific data. Only limited and mostly confidential information is available for the EEE relevant HIPS that comes along with emission release information of EPS as both activities can often not be separated.

Generally, releases of HBCDD to the environment may occur over the whole life-cycle as a result of the production and micronisation, formulation, industrial use, professional and private use, service life and waste management.

For all sites during HBCDD production, formulation and industrial use emission release into bodies of water and soil are determined. In addition, emission release from products and waste containing HBCDD occurs. Polymer end-products containing HBCDD will accumulate on landfill sites and will finally cause release of the substance from the matrix. Some amounts of end-products containing HBCDD are incinerated. According to the RAR, well-functioning incinerators keep the emission releases at acceptable levels, whereas uncontrolled fires may result in the formation of polybrominated dibenzo-p-dioxin (PBDDs) and polybrominated dibenzofurans (PBDFs).

There is little life cycle information about HIPS in the EU RAR. The formulation and use of HIPS releases emissions to the air, wastewater and surface water.

Risk characterisation

According to the EU RAR with respect to formulation and industrial use of HIPS there is at present no need for further information and/or testing and for risk reduction measures beyond those which are already being applied for the EEE relevant applications. Considering secondary poisoning there is a need for limiting the risks. Risk reduction measures which are already being applied shall be taken into account.

However, risk characterization may also take the following findings into account described by the next section, monitoring.

Monitoring

According to monitoring studies, HBCDD levels are found in European fish, marine mammals especially seal and porpoise, marine birds eggs and further biota such as freshwater fish and terrestrial birds.

HBCDD has been detected in very remote areas, such as in air in northern Sweden and Finland, far from potential sources. HBCDD has also been found in fish from Swiss mountain lakes, in mussels from Lofoten and Varanger and liver from Atlantic cod from northern Norway, in Polar cod and ringed seal from Svalbard in the arctic region, in marine bird and bird eggs from northern Norway, and in polar bears from Greenland and Svalbard in the Artic Ocean. Therefore, HBCDD is assumed to undergo long-range atmospheric transport. In addition, many studies suggest an increase in the concentration of HBCDD in biota over time (Risk Assessment Hexabromocyclododecane, 2007).

Human health

Exposure

HBCDD may affect the human population by inhalation of vapour and airborne dust, ingestion and via dermal contact. Highest exposure can be found at the workplace.

Occupational exposure

Possible exposure may occur by inhalation and dermal exposure. Different scenarios are examined concerning the exposure during the manufacture, industrial use and sewing of HBCDD. According to the RAR, as polystyrene flame-retarded with HBCDD (EPS-F, XPS-F and HIPS-F) contains HBCDD in concentrations of 0.5-5%, the exposure to HBCDD during dust generation handling of these materials will be low.

Consumer exposure

The release of HBCDD from products depends on the concentration of HBCDD in the product, the mobility of HBCDD in the matrix, the relative surface area of the product and the physical conditions of the surrounding media. The concentration of HBCDD in HIPS is assumed to be much lower (approx. 1/8) than in textile latex coating and higher (approx. 3 times) than in XPS and EPS. Due to low vapour pressure the release to the air from products is assumed to be relatively low. Dermal exposure in the case of direct dermal contact with products containing HBCDD is possible. The exposure from HIPS is not further examined.

Indirect exposure via the environment

Due to persistent and bioaccumulative characteristics of HBCDD the exposure to man via food can be assumed as an important route of exposure. This originates mainly from ingestion of fish and root crops. Since 1998 studies in the EU on the concentration of HBCDD in biota and food have identified an indirect intake of HBCDD from biota such as fish. There are findings of HBCDD in human breast milk, according to four Scandinavian studies.

The RAR mentions that not all exposed consumers may have been identified due to difficulties in obtaining information. In addition, a large part of the production of HBCDD may be used in Eastern Europe with no information about the emission release.

Risk characterisation

There are currently no occupational exposure limit values. According to the EU RAR there is a need to establish occupational exposure limit values for HBCDD. With respect to consumer exposure, further information and/or testing and risk reduction measures beyond those which are already being applied for the EEE relevant applications are not necessary. Repeated dose toxicity to man exposed via the environment from local or regional sources and from exposure via breast milk is not of concern, according to the EU RAR. Here, the calculated data by EUSES modelling and the measured data on which the previous conclusion relies on differ largely.

3.2.5 Disposal and recycling

It is not known to the RAR what amounts of end-products containing HBCDD are put on a landfill, are incinerated, left in the environment or recycled. There is waste produced at each life cycle step. In the case of incineration when using inadequate incineration techniques PBDDs and PBDFs can be formed.

No specific information is given on the disposal and recycling of EEE relevant products.

3.2.6 References

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- KEMI (2007): Strategy for limiting risks – Hexabromocyclododecane (HBCDD), Draft September 2007, inedited.
- Risk Assessment Hexabromocyclododecane. Final Draft October (2007).

3.3 Specific phthalates: DEHP, BBP and DBP

The following chapter gives general information on phthalates. The chapters 3.4, 3.5 and 3.6 refer to the specific phthalates DEHP, BBP and DBP, respectively.

Phthalate esters are the dialkyl or alkyl aryl esters of 1,2-benzenedicarboxylic acid. The phthalates show low water solubility, high oil solubility, and low volatility. They are produced by reacting phthalic anhydride with an appropriate alcohol (usually 6 to 13 carbon).

Some phthalates are discrete chemicals, such as DEHP, while others are complex mixtures of isomers, such as DINP and DIDP. Each one of the latter is a group of very closely related chemicals or isomers, with the same overall molecular formula but slightly different structures.

3.3.1 Use

Phthalates are mainly used as plasticizers (or softeners) in plastics, especially in flexible PVC (e.g. in cables and other flexible components), but also in rubber, paint and glue. Plasticisers have the function of improving the polymer material’s flexibility, workability and distendability. In flexible PVC products the typical phthalate content ranges from 35–45% (COWI 2001).

Phthalates that are incorporated into plastic materials are not chemically bound to the plastic, but dispersed in the matrix. Thus, they may be released out of the material over time. This can result in substantial losses to the environment during the lifetime of products and during their disposal (Andersson 2005; Greenpeace 2007). Leaching out from certain applications and transportation in the air seems to be the major routes of entering the environment for certain of the phthalates.

The most widely-used phthalates are di-2-ethyl hexyl phthalate (DEHP), diisodecyl phthalate (DIDP) and diisononyl phthalate (DINP).

The estimated consumption of phthalates in Western Europe was 894,000 tonnes in the years 1990 to 1995. Based on industry data, the annual use of DEHP was 476,000 tonnes/year in 1999. The use of DEHP has decreased significantly during the last years in favour of DINP and DIDP (Andersson 2005; EU RAR DEHP 2001).

Table 5 Data on the total amount used in the EU, the amount used for PVC and polymers and the amount used for PVC in cables and wires for DEHP, DBP, BBP, DINP and DIDP; tonnes/year (tpa).

Phthalates	Total amount used in the EU	Amount used for PVC / polymers	Amount used for PVC in cables & wires
Bis (2-ethylhexyl) phthalate (DEHP)	476,000 tpa in 1997	462,000 tpa in 1997	80,920 tpa in 1997
Dibutylphthalate (DBP)	18,000 tpa in 1998	13,500 tpa in 1998	Not specified
Butyl benzyl phthalate (BBP)	19,500 tpa in 2004	8,000 tpa in 2004	Non - very little
Diisononyl phthalate (DINP)	107,200 tpa in 1994	101,840 tpa in 1994	29,020 tpa in 1994
1,2-Benzenedicarboxylic acid diisodecyl ester (DIDP)	199,480 tpa in 1994	190,503 tpa in 1994	54,807 tpa in 1994

3.3.2 Classification

Table 6 Phthalates and their hazard classification

Phthalates	CAS Numbers	Classification Human Health	Classification Environment	Endocrine disruption (according to EDS[22])	PBT and vBvP Classification	SVHC
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	-	EDS database Cat. 1[23]	Not considered as PBT substance, but borderline case; has the potential to bioaccumulate	Yes
Butyl benzyl phthalate (BBP)	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62	N; R50-53	EDS database Cat. 1	Not considered as PBT substance	Yes
Dibutylphthalate (DBP)	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62	N; R50	EDS database Cat. 1	Not considered as PBT substance	Yes
Diisononyl phthalate (DINP)	28553-12-0 and 68515-48-0	No classification	-	No endocrine disrupting effect	Not considered as PBT substance	No
1,2-Benzenedicarboxylic acid diisodecyl ester (DIDP)	26761-40-0 and 68515-49-1	No classification	-	No endocrine disrupting effect	Not considered as PBT substance	No
Di-n-octyl phthalate (DNOP)	117-84-0	No classification	-	No endocrine disrupting effect	Not considered as PBT substance	No

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[22] Petersen, G. et al. (2007)

[23] EDS Cat. 1: at least one in vivo study providing clear evidence for endocrine disruption in an intact organism

3.3.3 Legislation

The use of some phthalates is restricted in the European Union for use in toys and products for children. DEHP, BBP, and DBP are restricted for all toys; DINP, DIDP, and DNOP are restricted only in toys that can be taken into the mouth[24]. The restriction states that the amount of phthalates may not be greater than 0.1% mass percent of the plasticized part of the toy.

The classification of certain phthalates (including DEHP) in the EU as ‘toxic to reproduction’ results in their prohibition for use in certain other product groups, including cosmetic[25].

The Swedish Government has presented a bill on “Swedish environmental quality objectives” which aims at reducing the use of the main phthalate DEHP (and other plasticizers with harmful effects) through voluntary basis for outdoor use of PVC in coated woven fabrics and coated plate and for corrosion protection in cars by 2001. Other uses of DEHP as a plasticizer in PVC, with the exception of medical products and drugs, should be phased out on a voluntary basis by 2001. The Danish government has adopted an action plan to reduce the use of phthalates by 50% over the next 10 years. The German Federal Environmental Agency (Umweltbundesamt, UBA) recommends a phase-out of flexible PVC, for those applications where safer alternatives are available, due to the permanent loss of softeners, in particular phthalates, into the environment (Andersson 2005; UBA 2007).

3.3.4 Monitoring

Monitoring data in the aquatic compartment show that DEHP is ubiquitous in the environmental compartments; however the monitoring focused on urban and industrial areas. DEHP is measured in all biota samples investigated. The general exposure via the environment and the infant exposure via breast milk are considered to pose a risk for children. Monitoring data for DBP and BBP in environmental compartments and biota are quite scarce but also indicate a ubiquitous presence of these phthalates.

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[24] EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:344:0040:0043:EN:PDF

[25] EC (2004) Directive 2004/93/EC of the European Parliament and of the Council of 21 September 2004 amending Council Directive 76/768/EEC on the approximation of the laws of the Member States relating to cosmetic products. Official Journal of the European Communities L300, 25.9.2004: 13-41 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1976L0768:20060809:EN:PDF

3.3.5 References

- Andersson, E. (2005): Hazardous substances in electrical and electronic equipment (EEE) – expanding the scope of the RoHS directive; Göteborg University, Sweden & Swedish Chemicals Inspectorate (KemI).
- COWI – Consulting Engineers and Planners AS (2001): Environmental and Health Assessment of Alternatives to Phthalates and to flexible PVC. Environmental Project No. 590 2001, Miljøprojekt.
- EU Risk Assessment Report Bis(2-ethylhexyl) phthalate (DEHP), Consolidated Final Report (2001).
- EU Risk Assessment Report Benzyl butyl phthalate (BBP), Final Draft (2005).
- EU Risk Assessment Dibutylphthalate (DBP), Final Report (2003).
- European Union Risk Assessment Report 1,2-Benzenedicarboxylic Acid, Di-C9-11-Branched Alkyl Esters, C10-Rich and Di-“Isodecyl” Phthalate (DIDP), Final Report, (2003).
- European Union Risk Assessment Report 1,2-Benzenedicarboxylic Acid, Di-C8-10-Branched Alkyl Esters, C9-Rich and Di-“Isononyl” Phthalate (DINP), Final Report, (2003).
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- Petersen, G. et al. (2007): Study on enhancing the Endocrine Disrupter priority list with a focus on low production volume chemicals; DHI Water & Environment; Revised report to DG Environment ENV.D.4/ETU/2005/0028r
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- UBA – Umweltbundesamt (2007): Phthalate – Die nützlichen Weichmacher mit unerwünschten Eigenschaften. http://www.umweltbundesamt.de/uba-info-presse/hintergrund/weichmacher.pdf
- TNO – Netherlands Organisation for Applied Scientific Research (2001): Alternatives for phthalates. TNO-Report STB-01-55, Delft.

3.4 *Phthalates, I:* Bis (2-ethylhexyl) phthalate (DEHP)

3.4.1 Use

DEHP is assumed to make up 51% of the total phthalate plasticizers. The total consumption of DEHP was 476,000 tonnes/year in 1997(EU RAR DEHP, 2001). DEHP is to 97% used as a plasticizer in polymer products, mainly PVC (462,000 tonnes/year in 1997). EEE relevant applications of flexible PVC are insulation for cables and wires (80,920 tonnes/year in 1997) and other flexible components.

The remaining three per cent of the total DEHP (14,280 tonnes/year in 1997) is used for non-polymer applications, among others in ceramics for electronic purposes. Phthalates can be used as additives for ceramics to improve their processability. Other use is as dielectric fluid in capacitors (40 tonnes/year for this application sold by one producer).

3.4.2 Current legislation

Please refer to section 3.3.3 above.

In addition, there are different Occupational Exposure Limits for DEHP according to national legislation; the lowest level is ruled out by Denmark and Sweden, the highest level by Germany. Some countries also regulated Short Term Exposure Limits that differ as well.

DEHP is listed as priority substances under the Water Framework Directive and is subject to a review for identification as a possible “priority hazardous substance” (OSPAR, 2006).

3.4.3 Classification

Classification according to Annex I to Directive 67/548/EEC:

Human health	Reprotoxic Category 2; R 60-61
Environment	None

Endocrine disruption

The specific endocrine activity (estrogenic, anti-androgenic, anti-estrogenic) of DEHP is not clear (OSPAR 2006). *In vivo* and *in vitro* studies indicate that DEHP can interfere with the endocrine function and also influence the sexual differentiation. Studies in rats and Atlantic salmon (*Salmo salar*) support the hypothesis that DEHP may exert an antiandrogen effect. So, DEHP might have a potential endocrine disrupting effect in aquatic species at realistic exposure concentrations. DEHP is classified as reprotoxic in many mammalian species with testes being the target organ.

According to the EU EDS Database DEHP is assigned to Category 1 showing evidence of endocrine disrupting activity in at least one species using intact animals (Petersen et al. 2007).

Mono (2-ethylhexyl) phthalate (MEHP) is the major metabolite when DEHP is degraded in the environment and in biota. MEHP has proven to be toxic in studies with mammals. The substance could be responsible for many of the effects seen in toxicity studies with DEHP. MEHP is probably also toxic to other species like birds, fish, frogs etc. However, no such information is available.

PBT and vPvB evaluation

DEHP is not considered a PBT substance although it is a borderline case. It is not considered persistent, but has a potential for bioaccumulation which does not meet the EU-TGD B criterion but exceeds the OSPAR criterion for bioaccumulation (OSPAR 2006). Based on the above BCF values, DEHP has the potential to bioaccumulate in the aquatic environment. It has also potential of reprotoxicity for mammalian species.

SVHC

Due to its classification as “toxic to reproduction (category 2, R60-61)“ fulfilling the T-criterion, DEHP is a substance of very high concern.

3.4.4 Risk assessment

As plasticizers are not chemically bound to the matrix polymer in flexible PVC (or other materials), DEHP migrates slowly from polymer products during their entire lifetime. The emitted DEHP will evaporate, precipitate, biodegrade or be adsorbed to organic matter.

Exposure analysis indicates that the main part of DEHP is released by widely dispersed use and disposal of polymer products.

Environment

DEHP enters the environment mainly via direct release to the air, release from sewage sludge and from solid waste. Due to the large amount of DEHP used annually and the use pattern in many articles with long service life, large amounts of DEHP are diffusely spread in the environment. DEHP is therefore found in all environmental compartments, also in remote areas. The extent of formation of MEHP in the environment is unknown, but probably considerable.

Generally, no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already were concluded by the EU RAR DEHP, 2001.

However there is a need for limiting the risks for some environmental compartments under certain condition (aquatic ecosystem because of concern for birds consuming mussels exposed to DEHP near sites processing polymers with DEHP or sites producing sealants and/or adhesives with DEHP; terrestrial ecosystem because of concern for mammals consuming earthworms exposed to DEHP near sites processing polymers with DEHP or sites producing lacquers, paints, printing inks, sealants and/or adhesives with DEHP); risk reduction measures which are already being applied shall be taken into account. Studies with exposure via the food indicate effects on fish, where a need for further information and/or testing was addressed by the EU RA DEHP 2001.

So, for the river basins where emissions of DEHP may cause a risk, the relevant Member State(s) establish EQSs and the national pollution reduction measures to achieve those EQS in 2015 shall be included in the river basin management plans in line with the provisions of Council and Parliament Directive 2000/60/EC (Water Framework Directive).[26]

Human health

Workers

There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account.

Occupational exposure during the industrial use of DEHP is considered to be the highest. There is concern for the testicular, fertility, RDT and developmental endpoints for workers. There is no concern for the acute toxicity, irritation and sensitising effects, carcinogenicity, and mutagenicity.

The European Commission recommends establishing Occupational Exposure Limit values for DEHP according to Council Directive 98/24/EC (3)[27] at community level.

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[26] Commission Recommendation of 6 December 2007 on risk reduction measures for the substances: Piperazine; Cyclohexane; Methylenediphenyl diisocyanate; But-2yne-1,4-diol; Methyloxirane; Aniline; 2-Ethylhexylacrylate; 1,4-Dichlorobenzene; 3,5-dinitro-2,6-dimethyl-4-tert-butylacetophenone; Di-(2-ethylhexyl)phthalate; Phenol; 5-tert-butyl-2,4,6-trinitro-m-xylene. Official Journal of the European Union L 33/8 7.2.2008.

[27] European Commission (2008): Commission communication on the results of the risk evaluation and the risk reduction strategies for the substances: Piperazine; Cyclohexane; Methylenediphenyl diisocyanate; But-2yne-1,4-diol; Methyloxirane; Aniline; 2-Ethylhexylacrylate; 1,4-Dichlorobenzene; 3,5-dinitro-2,6-dimethyl-4-tertbutylacetophenone; Di-(2-ethylhexyl)phthalate; Phenol; 5-tert-butyl-2,4,6-trinitro-m-xylene. Official Journal of the European Union C 34/1. 7.2.2008

Consumers

EEE applications of DEHP are not considered to be relevant for consumers as of cable insulation, only a small fraction of their total area would be available to emit DEHP.

However, due to the wide use of DEHP in the society and the diffuse emissions from the products, humans may be exposed from many different sources via food and via medical products and use of end products, but also indirectly via the environment by food, water and air may occur as a result of emissions to the environment from all life cycle stages. Characterisation of combined exposure indicates reason for concern. However, it is recognised that assessment of this type of information is difficult.

Especially because of the concerns for children, the European Commission recommends to restrict the use of DEHP in packaging materials for foods (plastic materials in contact with food (Directive 2002/72/EC (4) and to consider restricting the use of DEHP in medical devices and to consider at Community level restrictions for the use of DEHP in industrial installations for processing polymers with DEHP (extrusion, calendaring, spread coating) and for producing sealants and/or adhesives, paints and lacquers or printing inks with DEHP, exempting installations with no emission of DEHP to the environment as well as installations where DEHP emissions are adequately controlled.

3.4.5 Recovery and disposal

The contribution of emissions from waste is assumed to be high. Disposed material may either be placed in a landfill or incinerated. A fraction of the disposed material is expected to remain in the environment after end use.

The municipal landfills are identified to emit DEHP mainly through the leakage water. Incineration stations emit DEHP through the air. However, for the waste management no additional reduction measures are discussed.

No information on recovery has been submitted.

3.5 *Phthalates, II:* Butyl benzyl phthalate (BBP)

3.5.1 Use

According to industry data, estimated 19,500 tonnes/year BBP were used within the EU in 2004. The main use of BBP is as a softener in PVC products, especially in flooring (8,000 tonnes/year in 2004 accounting for 41% of the total use volume). About 6,000 tonnes/year are used in sealants while the remaining 5,500 tonnes/year are not further specified. No use of BBP for EEE is specified in the EU RAR BBP, 2005; also detailed figures for all the respective use patterns did not refer to any EEE application.

According to the EU RA, BBP seems to be of minor relevance for the production of EEE.

3.5.2 Current legislation

Only a few countries have defined occupational exposure limits for BBP and/or for all isomers of phthalates (United Kingdom, Ireland, Netherlands, Sweden and Denmark) or for some phthalate (Norway).

3.5.3 Classification

Classification according to Annex I to Directive 67/548

Human health	Reprotoxic Category 2; R61 - BBP affects development Reprotoxic Category 3; R62 - Possible risk of impaired fertility Symbol: T[28]
Environment	N; R50-53. Symbol: N

BBP appears to be a borderline case between no classification for carcinogenicity and Carcinogenic Category 3. However, due to the lack of genotoxic effects no classification is proposed.

Endocrine disruption

According to the EU EDS Database BBP is assigned to Category 1 showing evidence of endocrine disrupting activity in at least one species using intact animals (Petersen et al. 2007).

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[28] The rapporteur of the part on Human Health (Draft Report March 2004 as part two in the RAR) proposed the following classification of BBP for Human Health:
T; Repr. Cat. 2; R-phrase: 61
Xn; Repr. Cat. 3; R-phrase: 62
The decision for the final classification as T is not discussed.

PBT and vPvB evaluation

Neither the OSPAR screening criteria nor the EU criteria for persistency and bioaccumulation are fulfilled. Therefore BBP cannot be considered as a PBT chemical.

SVHC

Due to its classification as “reprotoxic category 2”, BBP is a substance of very high concern fulfilling the criteria given in REACH Art. 57 c.

3.5.4 Risk assessment

BBP used as softener is not chemically bound to the matrix. Thus, it can migrate from the polymeric material and become available for emissions to other matrices (environmental or biological). BBP can be released from polymer based products during its use or after disposal.

Environment

Exposure can occur during production, transport, use (which is assessed product specifically) during incineration by fly ash and landfill (under anoxic conditions the BBP is degraded to its monoesters).

For all life cycle steps and environmental compartments, the RAR concludes that there is at present no need for further information and/or testing and for risk reduction measures beyond those which are being applied already. Only for surface water (including sediment), this conclusion has to be seen as provisional until possible endocrine effects in fish have been resolved.

Human health

There is at present no need for further information and/or testing and for risk reduction measures beyond those which are being applied already. This conclusion was reached for both occupational and consumer exposure.

Workers

The main routes of exposure for workers are expected to be by inhalation and dermal contact. Ingestion is not considered to be relevant for occupational exposure. The available toxicological and exposure data do not indicate any concern for BBP with respect to any of the considered endpoints or scenarios.

Consumers

Consumer exposure is considered for cellophane food packaging, for indoor air and for baby equipment/children toys, but not for any EEE application.

For consumers and humans exposed indirectly via the environment, the main exposure is expected to be from ingestion. Even the evaluation for combined exposure does not indicate any reasons for concern, according to the RAR.

3.6 *Phthalates, III:* Dibutylphthalate (DBP)

3.6.1 Use

The largest usage of DBP in general is as a plasticizer in resins and polymers such as polyvinylchloride (PVC). Based on 1997 data, on average around 76% of DBP is used as a plasticizer in polymers (11,000 tonnes/year), 14% in adhesives (2,000 tonnes/year), 7% in printing inks (1,300 tonnes/year) and the remaining 3% is used in miscellaneous other applications (500 tonnes/year) (EU RAR DBP 2003).

3.6.2 Current legislation

Please refer to section 3.3.3 above.

3.6.3 Classification

Classification according to Directive 67/548/EEC:

Human health	Reprotoxic Category 2; R61: - May cause harm to the unborn child. Reprotoxic Category 3; R62: - Possible risk of impaired fertility.
Environment	N; R50: - Very toxic to aquatic organisms.

Endocrine disruption

According to the EU EDS Database DBP is assigned to Category 1 showing evidence of endocrine disrupting activity in at least one species using intact animals (Petersen et al. 2007).

DBP is considered as a potential endocrine disrupter by OSPAR (OSPAR 2006) and is therefore listed as “Chemical for Priority Action” (OSPAR Commission, Update 2007).

PBT and vPvB evaluation

DBP is not classified as PBT substance: it does not fulfil criteria for persistence and bioaccumulation. However, toxicity criterion is fulfilled because of its classification as "reprotoxic category 2".

DBP is expected to degrade relatively rapidly in the environment and the bioaccumulative potential is expected to be low in the food chain (OSPAR 2006).

SVHC

Due to its classification as "reprotoxic category 2", DBP is a substance of very high concern fulfilling the criteria given in REACH Art. 57 c.

3.6.4 Risk assessment

In the EU Risk Assessment the environmental exposure assessment of DBP was based on the expected releases of DBP during the life cycle stages production, distribution, processing, use of DBP containing products and incineration/disposal of DBP containing products.

With regard to the processing, a distinction is made in the exposure assessment between PVC processing, processing of adhesives, printing inks, glass fibres and grouting agents. The main application of DBP in electrical and electronic equipment is its use as plasticizer in PVC cables. Therefore, the use of DBP in EEE is covered by the exposure scenario for "PVC processing".

The following conclusions were drawn in the EU RA DBP 2005 concerning the risk of DBP to human health and environment:

Environment

There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account.

This conclusion is reached because of anticipated risk for plants via atmospheric exposure at a local scale.

Human health

Workers

There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account.

This conclusion is reached because of:

- concerns for general systemic toxicity as a consequence of repeated dermal exposure arising from aerosol forming activities;
- concerns for adverse local effects in the respiratory tract as a consequence of repeated inhalation exposure in all occupational exposure scenarios.

Consumers

There is at present no need for further information or testing or risk reduction measures beyond those which are being applied already.

3.7 *Phthalates, IV:* Diisononyl phthalate (DINP), 1,2-Benzenedicarboxylic acid diisodecyl ester (DIDP) and Di-n-octyl phthalate (DNOP)

Diisononyl phthalate (DINP), 1,2-Benzenedicarboxylic acid diisodecyl ester (DIDP) and Di-n-octyl phthalate (DNOP) are not classified according to Annex I to 67/548/EEC, do not fulfil the criteria for PBT/vPvB substances according to REACH and do not show endocrine disrupting effects. They are not considered as high priority substances within the scope of this project and therefore not further evaluated. Risk assessment reports are, however, available for DINP and DIDP.

There are tendencies by the industry to reduce the use of DEHP, DBP and BBP and to instead use DINP und DIDP, increasingly. The German Federal Environmental Agency (Umweltbundesamt) warns against this substitution because DINP and DIDP possess a similar chemical structure as DEHP and are used in very high amounts so that a risky spread in the environment is anticipated. DINP and DIDP show a high bioaccumulation potential. DINP metabolites have been found in the general public (Koch 2005). A recent human biomonitoring study has shown a slight increase in the daily uptake of DINP in the period from 1988–2003 (UBA 2007).

3.8 Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, Chloro)

Part II of the EU RAR on human health has not been available up to the time of report preparation. Information on human health has been taken from SCHER (2008).

3.8.1 Use

The main uses of medium-chain chlorinated paraffins (MCCPs) are as secondary plasticizers / softener and as flame retardant in PVC. PVC production accounts for about 80% of the MCCP use (51,827 tonnes in 1997). Secondary plasticizers, when used in combination with primary plasticisers, cause an enhancement of the plasticising effects and so are also known as extenders.

In addition, MCCPs are used as lubricants and additives in metal working/cutting (5,953 tonnes), and as softener and flame retardant in paints, sealants, adhesives (3,541 tonnes) and in rubber and polymers (1,048 tonnes) (others than PVC) as well as in carbonless copy paper (741 tonnes).

EEE relevant appliances of MCCP are in flexible PVC such as in cable sheathing and insulation. Here, MCCP with higher degrees of chlorination (typically around 50-52% wt. Cl) are used (high degree of chlorination reduces the potential for migration from the final product[29], but also reduces its flexibility). In a cable compound the more highly chlorinated substances are more compatible with the PVC and can be used at higher concentrations than usually added. So, MCCP with 52% wt. Cl make up around 2/3 of the 51,827 tonnes used for PVC production. The actual amounts of MCCPs used in the various PVC applications considered are less well defined than is the case for Di(2-ethylhexyl)phthalat (DEHP). One supplier indicates that 17% of the total supplied for PVC applications is used in cable products. Based on this figure, 9200 tonnes/year of MCCP are used for cable products.

The use of MCCP in plastics other than PVC can be considered to be primarily as a flame retardant additive. If MCCP is used specifically as a flame retardant in e.g. plastics, chlorinated paraffins with a high degree of chlorination (e.g. 70-72% wt. Cl) are used, along with a synergist e.g. antimony trioxide.

The exact amounts of EEE relevant uses of MCCP are not given in the EU RAR.

3.8.2 Current legislation

Some uses of MCCPs are covered under the Integrated Pollution Prevention and Control Directive (Directive 1996/61/EC), e.g. large production sites of metal working, some PVC and plastics compounding/conversion sites and leather processing sites.

Additionally, some national legislations cover the use of MCCP containing products:

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[29] C14-17, 52% wt. Cl substance is around 1.4 times more volatile than DEHP from PVC.

- In Germany, chlorinated paraffin-containing wastes, e.g. metal working fluids with > 2 g halogen/kg and halogen-containing plasticizers, are classified as potentially hazardous waste and are incinerated.
- In Norway, MCCPs are included in the national "List of Priority Substances" for which emissions are to be substantially reduced by 2010 at the latest.
- Within the UK, the MCCPs User Forum formed in 2001 by users and suppliers voluntarily agreed on the reduction of risks to the UK environment from MCCPs, especially a reduction in emission. Users committed to adopt and encourage best practice.

3.8.3 Classification

MCCPs are currently not classified with respect to their effects on human health or the environment.

The rapporteur suggests the following classification for the environment:

Environment	N; R50/53 - Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

It is proposed to classify MCCPs with the risk phrase "May cause harm to breast-fed babies" (SFT, 2007).

Endocrine disruption

According to the EDS database, MCCPs are assigned endocrine disruption Cat. 1. This implies that at least one in-vivo study provides clear evidence for endocrine disruption in an intact organism.

PBT and vPvB evaluation

Medium-chain chlorinated paraffins have a high acute toxicity towards aquatic organisms, a high fish bioconcentration factor and are poorly degradable.

MCCP has a high potential for bioaccumulation as they are taken up by organisms from water, sediment/soil and food. However, the measurement of the accumulation/biomagnification factor is very difficult for complex substances such as MCCPs.

In sludge, adsorption of MCCPs is high. In soil and sediment, MCCPs are expected to be relatively immobile. Thus, MCCPs are not expected to leach from soil into groundwater. A problem is, that the actual bioavailability and environmental behaviour of the MCCPs within the particles of the final product are unknown as well as the actual (bio)availability of the

MCCPs released to the environment because of the high adsorbtion and uncertainties over the actual residence time of the substance in the soil.

In conclusion, MCCP fulfils the persistence criterion, however the bioaccumulation criterion needs further testing. Further, it is very toxic to aquatic organisms (UBA, 2003).

SVHC

MCCPs are substances of very high concern as defined by REACH. This classification is based on the fact that MCCPs have endocrine disrupting properties (Cat. 1).

3.8.4 Risk assessment

Environment

Exposure

During production of MCCP emission releases to the wastewater and surface water are calculated. During all the different sort of uses such as in PVC, rubber and polymer formulation, processing and service life emission releases to wastewater and to air occur.

According to the UCD (1998), the typical total plasticiser level in flexible PVC is 30-50%. Therefore, 250 tonnes/year plasticiser is equivalent to a production of around 500-830 tonnes/year of flexible PVC. Concerning flexible PVC relevant uses, the raw material handling can result in a minimal loss by spillage. During compounding losses to air from the hot material occur due to the volatile behaviour of MCCP. With respect to PVC processing, cables and wires are mainly produced by extrusion which can be a partially open or a closed system. There is no emission/exposure from the extruder itself. The main source of release is likely when the hot material leaves the die.

Risk characterisation

There are uncertainties inherent to the risk assessment because MCCPs are a complex mixture (of different carbon chain length, degrees of chlorination and position of the chlorine atoms along the carbon chain) and are therefore difficult to test in many of the standard assays.

There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account. These conclusions were reached for the following compartments and applications that are relevant for EEE:

- For surface water and the use of MCCP in several stages of production of PVC (particularly where compounding or compounding and conversion are carried out in partially open systems).

- For sediment and the terrestrial compartment and the production of PVC, especially during extrusion and compounding and production steps that are relevant for PVC cable manufacturing.
- For secondary poisoning, a risk is identified for the earthworm food chain and concerns for the fish food chain are also indicated.

The RAR considered no need for further information and/or testing and for risk reduction measures beyond those which are being applied already for some EEE relevant applications and compartments (for waste water treatment plants and the atmospheric compartment generally from the production and use of MCCPs; for surface water from some PVC compounding and/or conversion sites; for sediment from some use in PVC (compounding in open and closed systems); for soil from PVC plastisol coatings compounding, conversion or combined compounding/conversion sites, PVC extrusion/other compounding sites, PVC extrusion/other conversion sites and PVC extrusion/other combined compounding/ conversion sites using open or closed processes).

Monitoring

Monitoring studies have measured concentrations of chlorinated paraffins, possibly MCCP, from a PVC cable manufacturer in biota, such as in Benthos, Sphaeridae, Lymnaeidae, Hirudinae with 0.8 mg/kg fresh weight. Apart from biota, in environmental media such as in sediment and water concentrations of MCCP have been detected by several studies.
MCCPs have been found in the food chain, including in fish, in cow milk and in breast milk. Monitoring data from Norway show widespread occurrence in the environment (SFT, 2007).

Human health

Part II of the EU RAR on human health has not been available up to the time of report preparation. Information on human health has been taken from SCHER (2008).

Occupational exposure

According to SCHER (2008), occupational exposure mainly occurs during the manufacture of products containing MCCP such as PVC, metal working fluids, flame retardants, rubber, etc. Measurements from workplaces that produce PVC give a maximum air concentration value of 1.2 mg/m³. The use of metal working fluids shows even higher levels. Dermal exposure is only reported for metal working fluids (SCHER, 2008).

Consumer exposure

Consumers cannot be exposed directly to MCCPs, but to products such as plastics and rubber containing this substance. However, the exposure from most applications has been considered to be negligible (SCHER, 2008).

Indirect exposure via the environment

Exposure via the uptake of food, air and drinking water was estimated on the basis of a study with carrots via root crops. Exposure values of 0.032 mg/kg/day locally and 2.6 x10^{-4} mg/kg/day regionally were determined (SCHER, 2008).

Risk characterisation

With respect to repeated dose toxicity, for some workplaces the risk has to be limited taking the risk reduction measures already being applied into account. For use of MCCP in oil-based metal working fluids this conclusion also applies as dermal exposure is high.

No further testing and/or information and risk reduction measures beyond those already being applied is concluded for consumer exposure and exposure via the environment (SCHER, 2008).

Risk management is being developed by Defra (the UK's Environment Ministry). Risk Reduction Strategies are supposed to be finalised by April 2008.

3.8.5 Disposal

Since MCCPs are not changed during their lifecycle, ultimately all the chlorinated paraffins used in products will be disposed of at the end of life of the product. Disposal by landfill or incineration is likely to be the ultimate destination of much of the chlorinated paraffin. The amount of MCCPs disposed of to landfill and incineration each year is estimated about 60,000 t. The vast majority of this amount is likely to be present in PVC articles.

In landfills, chlorinated paraffins may be expected to be relatively stable for a number of years and so could be subject to leaching or volatilisation from the landfill, but as MCCPs strongly adsorb onto soil, leaching and volatilisation from landfill is not expected to be significant.

During incineration processes, chlorinated paraffins can basically be a source of chlorine then leading to the formation of polychlorinated dioxins and furans. Besides unsaturated hydrocarbon products, including aromatic products such as polychlorinated biphenyls and polychlorinated naphthalene can also be formed under certain circumstances, such as under heat or in contact with alkaline substances. There is insufficient information available on this issue to make an assessment.

3.8.6 References

- EU Risk Assessment Report Alkanes, C14-17, chloro (MCCP), Part I – Environment Final Report (2005).
- SCHER – Scientific Committee on Health and Environmental Risks (2008): Risk Assessment Report on Alkanes, C14-17, chloro MCCP. Human Health Part, Directorate C: Public Health and Risk Assessment.
- UBA – Umweltbundesamt (2003): Leitfaden zur Anwendung umweltverträglicher Stoffe. TEIL FÜNF: Hinweise zur Substitution gefährlicher Stoffe. 5.4 Tenside und Emulgatoren, UBA, Berlin, Internet publication at http://www.umweltdaten.de/umweltvertraegliche-stoffe/Teil5_4.pdf.
- SFT (2007): Impact assessment of a proposal for prohibition on certain hazardous substances in consumer products; Norwegian Pollution control Authority.
- BERR (2008): Comments to list of high priority substances received during the Stakeholder Consultation on hazardous substances not regulated by RoHS; Department for Business, Enterprise and Regulatory Reform.

3.9 Short-chained chlorinated paraffins (SCCPs)

3.9.1 Use

In 1994, 13,208 tons SCCPs were used. The main uses of SCCPs are in metal working fluids (9,380 tons in 1994), sealants, as flame retardants in rubbers and textiles, in leather processing and in paints and coatings. For other application that may include EEE relevant applications, about 100 tons were used in 1994 (0.75 % of the total SCCP use). EEE applications are not pointed out in the EU RAR. According to industry statements, EEE applications are no longer used in PVC and are only found in metal working including moulding.

3.9.2 Current legislation

- Directive 76/769/EEC
  - Restricts uses as substances and as constituents of preparations for metal working and fat liquoring of leather.
  - Before 1 January 2003, the provisions on SCCP will be reviewed by the European Commission in cooperation with the Member States in the light of any relevant new scientific data on risks to health and the environment of SCCP.
- SCCPs are included in the priority list of Hazardous Substances of the European Water Framework Directive: Substances on this priority list will be subject to cessation or

phasing out of discharges, emissions and losses within an appropriate timetable that shall not exceed 20 years.

- SCCPs are proposed to be listed in Annexes A, B or C of the Stockholm Convention on Persistent Organic Pollutants (POP candidates), UNEP, 2007)

3.9.3 Classification

Classification according to Directive 67/548/EEC:

Human health	Xn; Carcinogen Category 3: R40 - Possible risk of irreversible effects.
Environment	N; R50/53: - Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Endocrine disruption

According to the EDS database, SCCPs are assigned endocrine disruption Cat. 1. This implies that at least one in-vivo study provides clear evidence for endocrine disruption in an intact organism.

PBT and vPvB evaluation

SCCPs are not readily biodegradable.

Short chain length chlorinated paraffins have been shown to bioconcentrate to a large extent in fish and molluscs. A high potential for bioaccumulation is suggested. Moreover, SCCPs are toxic substances. Therefore, SCCPs fulfil the PBT criteria.

SVHC

SCCPs are substances of very high concern as defined by REACH. This classification is based on the fact that SCCPs have endocrine disrupting properties (Cat. 1).

3.9.4 Risk assessment

Environment

Exposure

During production emissions are mainly released to the water. With respect to possible EEE applications, the emission release due to metal formulation and use mainly affects water and due to rubber formulations concerns soil, water and air. Releases due to paints and sealing compounds are negligible.

Risk characterisation

There is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account. This applies for the risk to aquatic organisms arising from the local emission of SCCPs from metal working and leather finishing applications, and also from the formulation of products for these uses. This conclusion also applies to secondary poisoning arising from formulation and use in leather finishing, and use in metal working applications.

The conclusion that further information and/or testing is needed applies for the sediment and soil compartment for production of SCCPs (sediment only), formulation and use of metal working fluids and leather finishing products, use in rubber formulations (sediment only), and also at the regional level.

For all other risks due to environmental exposure, the RAR concludes that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied already.

Monitoring

Monitoring study on biota usually report the level of total chlorinated paraffins. A few studies report measured levels of SCCPs in food, fish and marine animals and mussels. In addition, short and intermediate chain length chlorinated paraffins have been detected in birds, eggs and human foodstuffs in the United Kingdom. SCCPs have also been found in sheep near to a chlorinated production site and in rabbit muscles.

Human health

Occupational exposure

As SCCPs are viscous non-volatile liquids, dermal contact is the predominant occupational route of exposure. Inhalation exposure may occur during the formulation of hot melt adhesives, in the use of metal working fluids and during the spraying of paints, coatings and adhesives containing SCCPs.

Consumer exposure

Concerning the use of SCCPs in paints, sealants and adhesives and in rubbers, inhalation and dermal exposure arising from the use of finished products can be considered to be negligible. The use of SCCPs in metal working fluids available to consumers may result in exposure by dermal contact and inhalation.

Indirect exposure via the environment

According to some monitoring studies, SCCPs have been shown to bioconcentrate in aquatic organisms and has been detected in some items of food. In contrast, very low levels of chlorinated paraffins are expected to occur in air. The main route of indirect exposure via the environment is, therefore, likely to be via food and, to a lesser extent, drinking water.

Risk characterisation

There is at present no need for further information or testing or risk reduction measures beyond those which are being applied already. This applies for occupational and consumer exposure as well as indirect exposure via the environment.

3.9.5 References

- EU Risk Assessment Report Alkanes, C10-13, chloro, Final Report (1999).
- UNEP (2007): Summary of short-chained chlorinated paraffins proposal; Stockholm Convention on Persistent Organic Pollutants, Persistent Organic Pollutants Review Committee, Second meeting, Geneva, 6–10 November 2006 Item 6 (c) of the provisional agenda*, Consideration of chemicals newly proposed for inclusion in Annexes A, B or C of the Convention: Short-chained chlorinated paraffins.

3.10 Nonylphenol[30] and nonylphenol ethoxylates

3.10.1 Use

4-Nonylphenol is an industrial chemical, lubricant, pre- and decomposition product of emulsifiers and detergents. The major amount of nonylphenol is used for nonylphenol ethoxylates production which is used as surfactants in electrical and electronic engineering industry to a small extent. The production volume of nonylphenol in the EU amounts to 73,500 tonnes in 1997 with 60% being used for nonylphenol ethoxylates. Approximately 118,000 tonnes of nonylphenol ethoxylates were produced. After release into the environment, nonylphenol ethoxylates are degraded to nonylphenol.

EEE related uses that amount to 93 tonnes of nonylphenol ethoxylates in 1994 are fluxes in the manufacture of printed circuit boards, in dyes to detect cracks in printed circuit boards and as a component of chemical baths used in the etching of circuit boards. Moreover, cleaning products for some electrical equipment can contain nonylphenol ethoxylates. As cleaning products for some EEE are required to have less than 10 ppm of certain metal ions,

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[30] 4-nonylphenol (branched) and nonylphenol

a special grade nonylphenol ethoxylates would be needed to meet the requirements because the metal ion concentration is often far in excess of certain limits due to catalysts used in the nonylphenol ethoxylates production process. In the metal industry approximately 5% w/w of nonylphenol ethoxylates is reported to be used in cleaning products.

3.10.2 Current legislation

- PARCOM Recommendation 92/8 required signed countries to phase out nonylphenol ethoxylates in domestic detergents by 1995 and in all detergent applications by 2000.
- Several voluntary agreements of different EU countries on banning or reducing the use of nonylphenol
- Priority substance in the Water Framework Directive
- Directive 76/769/EEC restricts the use of nonylphenol in the following application:
    - industrial and institutional cleaning except:
        - controlled closed dry cleaning systems where the washing liquid is recycled or incinerated,
        - cleaning systems with special treatment where the washing liquid is recycled or incinerated;
    - domestic cleaning;
    - textiles and leather processing except:
        - processing with no release into waste water,
        - systems with special treatment where the process water is pre-treated to remove the organic fraction completely prior to biological waste water treatment (degreasing of sheepskin);
    - emulsifier in agricultural teat dips;
    - metal working except:
        - uses in controlled closed systems where the washing liquid is recycled or incinerated;
    - manufacturing of pulp and paper;
    - cosmetic products;
    - other personal care products except:
        - spermicides;
    - co-formulants in pesticides and biocides.

3.10.3 Classification

Nonylphenol is included in ANNEX I to Directive 67/548/EEC. The classification and labelling for human health and the environment is:

Human health	Xn; R22: - harmful if swallowed C; R43: - causes burns
Environment	N; R50-53: - Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment

Nonylphenol ethoxylates are classified as and labelled as N, R51/53 and R22, R41 depending on the degree of ethoxylation.

Endocrine disruption

According to the EU EDS Database, nonylphenol and nonylphenol ethoxylates are assigned to Category 1 showing evidence of endocrine disrupting activity in at least one species using intact animals. Studies on the oestrogenic effects of nonylphenol on fish and Daphnids show that nonylphenol and nonylphenol ethoxylates exhibit oestrogenic activity. Although the exposure levels are assumed to be low, nonylphenol and nonylphenol ethoxylate should be considered as an endocrine disruptor (UBA 2001a).

PBT and vPvB evaluation

The data from several tests on biodegradation indicate that nonylphenol undergoes biodegradation in water, sediment and soil systems, but results vary. Concerning persistence, nonylphenol is probably inherently biodegradable. According to the Fraunhofer-Institut (1999) and KEMI (1998), bioaccumulation potential has been found in fish and shell. Therefore, nonylphenol, the degradation products of nonylphenol ethoxylates, fulfils the bioaccumulation (B) criterion. In addition, nonylphenol is very toxic for aquatic organisms. Due to its inherent biodegradability, nonylphenol does not fulfil the persistency (P) criterion. Therefore, nonylphenol is not a PBT substance.

SVHC

Due to the fact that nonylphenol and nonylphenol ethoxylates have endocrine disrupting properties (Cat. 1), they are substances of very high concern as defined by REACH.

3.10.4 Risk assessment

Environment

Exposure

Environmental exposure of nonylphenol occurs during the production process and the different uses. Default emissions and site specific information is applied to determine environmental exposure. Concerning the release of nonylphenol by breaking down products containing nonylphenol groups such as nonylphenol ethoxylates, two types of emissions are possible: direct release of nonylphenol from the ethoxylates production process and the release of nonylphenol ethoxylates which may degrade in the environment to nonylphenol.

Risk characterisation

According to the EU RAR, there is no need for further testing and/or information for all life cycle stages affecting microorganisms in waste water treatment plants. With respect to surface water and sediment and the terrestrial compartment, the EEE relevant production, formulation uses of nonylphenol ethoxylates requires limited risk taking the risk measures being already applied into account. Release impacts to the atmosphere are regarded to be insignificant. Secondary poising shall be limited in its risk in some uses of nonylphenol ethoxylates including the use in electrical engineering. Uncertainties in this risk characterization remain given several reasons such as large variations in test results and default estimations.

Monitoring

Several monitoring studies have predominantly measured nonylphenol concentrations in surface water such as in Bavarian rivers and in the river Glatt in Switzerland, in sediments and wastewater treatment plants. Higher concentrations are reported in waters receiving effluent from industrial activities which use nonylphenol and nonylphenol ethoxylates indicating local hotspots. In addition, concentrations of nonylphenol ethoxylates have been measured in compost based upon green household waste and in non-contaminated soils in Denmark.

Human health

Occupational exposure

Human exposure occurs amongst others during the manufacturing of nonylphenol ethoxylates, using of nonylphenol as a chemical intermediate. Nonylphenol is manufactured and used as an intermediate in closed plants and, therefore, occupational exposure to nonylphenol is always likely to be low. Exposure only arises in the case of breaching during sampling, maintenance and product filling to drums or tanks by inhalation and dermal contact. There are generally no measures of occupational exposure to nonylphenol carried out by companies, only indirectly via measuring other hazardous substances. Dermal exposure was predicted by EASE to be in the range 0 to 0.1 mg/cm²/day for almost all activities. Activities such as maintenance are at the higher end of the range.

Consumer exposure

As nonylphenol is not directly used in end products, but used to make other products, consumers may be exposed to low levels of residuals, nonylphenol that has not yet reacted and nonylphenol due to a break down of the derivative compound. There is no information available for EEE relevant consumer exposure.

Indirect exposure via the environment

As emission releases of nonylphenol affect surface water and can bioconcentrate in aquatic organisms, nonylphenol may enter the food chain. Indirect exposure via the environment also occurs due to nonylphenol ethoxylates processing in the electrical engineering industry. Estimated human intake at the regional level is mainly by fish and roots. Uncertainty in the estimates remains. Therefore, further information on emissions into the local environment from production and use plants is necessary.

Risk characterisation

According to the EU RAR, the key health effects affecting workers and consumers are acute toxicity, corrosivity, repeated dose toxicity and impacts on the reproductive system. In the manufacture of nonylphenol and its use as an intermediate as well as in the application of speciality paints limited risk is needed taking into account the risk measures being applied already. In the case of the manufacture of speciality of paints, there is no need for further information and/or testing or for risk measures beyond those that are being applied already. This latter conclusion also applies to the risk characterization for consumers and for exposure via the environment at a regional level. However, there is a need for further information on emissions into the local environment from production and use plants.

3.10.5 Disposal and recycling

Direct disposal of nonylphenol is unlikely to happen. It will be released as part of a product. The disposal techniques of nonylphenol ethoxylates vary greatly, however, wastewater treatment on-site or at a local wastewater treatment plant and incineration of waste streams are usually used. The disposal stage for the use of nonylphenol ethoxylates in EEE relevant applications is not further considered in the EU RAR.

3.10.6 References

- EU Risk Assessment Report, 4-nonylphenol (branched) and nonylphenol, Final report (2002).
- UBA – Umweltbundesamt (2001a): Nachhaltigkeit und Vorsorge bei der Risikobewertung und beim Risikomanagement von Chemikalien, UBA, Nr.31/2001, Internet publication at http://www.umweltdaten.de/publikationen/fpdf-l/1968.pdf.

3.11 Beryllium

3.11.1 Use

Beryllium is mainly used as beryllium metal and composites, beryllium alloys and beryllium oxide in EEE appliances.

Beryllium metal and composites

(Containing 20% to 100% beryllium)

Applications:

- Structural members on satellites and spacecraft;
- Military and commercial guidance systems;
- Optical instruments;
- X-ray windows.

Beryllium-containing alloys

(Copper and nickel alloys contain from 0.15-2.0 weight percent beryllium)

Applications:

- Current carrying springs;
- Integrated circuitry sockets;
- Electrical and electronic connectors;
- Air bag sensors;
- Pressure responsive devices;
- Plastic injection molds;
- Fire extinguisher sprinkler heads;
- Aircraft landing gear bushings;
- Undersea repeater housings;
- Oilfield drill collars & friction bushings.

Beryllium oxide ceramic applications

Applications:

- Laser bores and tubes;
- Substrate for high speed integrated circuitry.

Beryllium metal and composites are rarely used in consumer electrical and electronic equipment. The main uses are in particle generation and detection equipment, nuclear fusion energy systems, optical instruments requiring high speed rotational applications such as ultra-high speed camera mirrors and optical scanning devices, in medical equipment, especially in X-ray equipment as well as in military targeting and guidance systems. Approximately 2 tonnes per year of beryllium are incorporated into these EEE applications in Europe.

Beryllium-containing alloys appliances amount to approximately 11.5 tonnes/year of beryllium. Most of it is increasingly used as copper beryllium alloys which are part of electrical contacts and connectors, suitable for electrical circuits in the electromagnetic radiation shielding and for miniaturisation of components such as connectors. Copper beryllium alloys consist of approximately 2% beryllium. Apart from copper beryllium alloys, beryllium-aluminium alloys gain in importance and can consist of up to 65% beryllium. They are used in a wide range of applications ranging from aerospace to computers (Andersson 2005).

Beryllium oxide ceramics add up to 1.5 tonnes/year of beryllium applied to high-end products and rarely to consumer EEE. They are used in photonics and laser applications such as in air cooled noble gas lasers for the laser bore as well as in concentrated photovoltaic cells, radio frequency applications such as travelling wave tubes, in power electronics and medical applications as a source of hard X-rays and high-energy electron beams. Beryllium oxide consumption is expected to increase in the long term because the demand for cooling devices and heat shields increases due to higher operating speed, for example in computers (Andersson 2005).

Among EEE applications that use beryllium-containing alloys, cellular phones typically contain the most beryllium at approximately 40 ppm (0.004% by weight). The share of beryllium in WEEE is estimated to be very low, according to beryllium related industry (Knudson 2008).

By taking figures of the United States to show the development of beryllium consumption, a total increase in consumption until 1999 mainly based on the rising usage of beryllium in electronics (Andersson 2005). From 1999 the consumption decreased to 190 tonnes in 2003 with 80% being used in EEE.

Some original equipment manufacturer have banned and restricted beryllium and beryllium compounds.

3.11.2 Current legislation

- EC Directive 84/360 'Combating of air pollution from industrial plants' controls industrial emissions of beryllium;
- Council Directive 91/689/EEC annex II and 2000/532/EC Article 2 on hazardous waste controls industrial emissions of beryllium by requiring recording and monitoring of hazardous waste. Waste containing more than 0.1% of beryllium is classified as hazardous.

3.11.3 Classification

Beryllium and beryllium oxide is classified, according to Annex I to Directive 67/548/EEC:

Human health	Carc. Cat 2; R49: possible carcinogenic effects by inhalation T+; R26: very toxic through inhalation T; R25-48/23: toxic if swallowed Xi; R36/37/38: irritation to eyes, respiratory organs and skin, R43: allergisation if skin contact
Environment (only for beryllium compounds with the exception of aluminium beryllium silicates, and with those specified elsewhere in the Annex I)	N; R51-53: - toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment

Endocrine disruption

No categorisation available, according to EU EDS Database.

PBT and vPvB evaluation

According to the EPA (2008), beryllium is not bioaccumulative. However, it is toxic. Overall, beryllium does not fulfil the criteria for a PBT or vPvB substance.

SVHC

Beryllium is a substance of very high concern as defined by REACH. This classification is based on the fact that Beryllium meets the criteria for classification as carcinogenic category 2.

3.11.4 Risk assessment

Environment and human health

Exposure

Apart from anthropogenic sources beryllium is naturally emitted into the atmosphere by windblown dusts and volcanic particles. Anthropogenic emission releases are estimated to amount to 45% of all airborne beryllium. However, the major emission source is the combustion of coal and fuel oil, due to beryllium-containing particulates and ash. Other beryllium-releasing industrial processes include ore processing, metal fabrication, beryllium oxide production, and waste handling and recycling which are estimated to account for 20% of the anthropogenic emissions (Knudson 2008).

Exposure to beryllium during ore mining and production is not possible within the EU because these operations are done outside the EU at very few sites (Bruce & Odin 2001). Apart from the occupational exposure during refining, smelting and extrusion of beryllium the manufacturing of beryllium-containing products also affects human health. For example, the occupational exposure is for EEE workers high (NIEHS, 2005). By inhalation of airborne beryllium in the form of dust, mist and fume, beryllium can induce a respiratory disease known as chronic beryllium disease (CBD). Many countries have adopted occupational exposure limits of 1-2 µg/m³ for a working day (Greenpeace International, 2005). The U.S. Occupational Safety and Health Administration (OSHA) sets the *Permissible Exposure Limit* (PEL) of 2 µg/m³ per working day. The U.S. National Institute for Occupational Safety and Health (NIOSH) recommended an Exposure Limit of 0.5 µg/m³. The State of California sets a Permissible Exposure Limit of 0.2 µg/m³ for occupational exposure (8 hour time-weighted average) (Kent et al. 2007).

For longterm inhalative exposure of the general public (not for occupational exposure), Schuhmacher-Wolz and Schneider (2004) proposed a reference concentration of 0.01µg/m³, refering to the study of Kreiss et al. (1996).

The main products that are used in the EU are beryllium metal, alloys and beryllium oxide ceramics. According to Knudson (2008), there is no inhalation risk associated with the massive forms in which the metals, alloys and ceramics are used. Beryllium metal as a hard and fully dense metal and beryllium oxide as a hard and fully dense ceramic does not reject any dust or fumes when it is supplied and used including the application in EEE, according to C4E (2002). With respect to copper beryllium alloys, inhalation risk which is controlled by existing workplace regulation can occur in certain component manufacturing operations such as grinding or welding. No respiratory risks arise from general handling, stamping and forming and most machining operations.

Beryllium oxide is associated with relatively high costs and, therefore, scarcely used, especially in high-end products where it remains environmental inert during its useful lifecycle stage. This also applies to beryllium metals and alloys which are also used in high-end products, and, in addition, to a low extent in consumer products such as mobile phones (Knudson 2008).

The life cycle stage, disposal and recycling, is regarded separately below.

Risk characterisation

There is no EU RAR available for beryllium. A potential occupational risk is associated with the manufacturing of beryllium-containing products and disposal and recycling. Occupational exposure limits are in place, but there is still ongoing discussion about the appropriate threshold limit values to prevent CBD and the derivation of a unit risk value related to the carcinogenicity of beryllium and beryllium oxide (Paustenbach et al. 2001; Schneider and Schuhmacher-Wolz 2004).

3.11.5 Disposal and recycling

Beryllium and beryllium oxide generate no exposure to the environment and human health when they are disposed of to a landfill, according to Knudson (2008). Five Winds International, LP (2001) found no information on the behaviour of beryllium in IT and telecom waste during incineration and landfill. However, beryllium is partly assumed to behave similar to other metals. Therefore, concentrations in incineration residues and mobilization from products in landfill leachates are possible.

Since beryllium oxide is very expensive the beryllium industry aims at recycling it. The recycle stream is very slow since the useful life of beryllium oxide containing products is extremely long. Products that contain beryllium metal and oxide ceramic compounds are recommended to be extracted for direct recycling as it is valuable as a clean scrap metal and usually do not enter the normal metal recycling stream. Beryllium metal scrap and copper beryllium scrap should not be remelted without appropriate controls (C4E 2002). Copper beryllium alloys are also fully recycled and its clean scrap produced during manufacture can enter the manufacture of new alloy directly. According to Andersson (2005), for recyclers of EEE it is difficult to identify beryllium containing components. Detailed information from the producer such as material declarations, therefore, has to be obtained for recycling.

Crushing, grinding or melting of products that contain beryllium, during recycling and disposal of scrap metal arising from its manufacture, may lead to inhalation risks due to airborne dust exposure. A study carried out by Kent et al. (2007) examined the impacts of airborne metal exposure among workers due to shredding, roasting, milling and assaying of recycled cellular phones. The findings show that the airborne beryllium exposures were below the *Permissible Exposure Limit* (PEL) of 2 µg/m³ per working day. This level was set by the U.S. Occupational Safety and Health Administration (OSHA). The U.S. National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit is 0.5 µg/m³. With respect to the reference concentration of long run inhalation exposure given by Schuhmacher-Wolz and Schneider (2004), shredding and roasting cause exactly this level of airborne beryllium exposure (0.01 µg/m³) whereas milling (0.02 µg/m³) and alloying (0.05 µg/m³) generates a higher exposure than the reference concentration. In the publication of Kent et al. (2007) details on the local exhaust ventilation hoods are given which are needed to assure the exposure levels as described in the study. In the study of Knudson 2008 it is assumed by the author that the recycling operations within the EU control any risk by using state of the art controls and practices. Contrary to this assumption it is reasonable to assume that a large part of the EEE waste streams is treated without application of comparable emission reduction measures (see also chapter 2.7).

Crushing, grinding, or melting of beryllium-containing products during recycling and disposal of scrap metal arising from its manufacture may lead to inhalation risks due to airborne dust exposure. A study carried out by Kent et al. (2007) examined the impacts of airborne metal exposure among workers due to shredding, roasting, milling and assaying of recycled cellular phones. Shredding and roasting processes during recycling of cellular phones caused mean airborne beryllium exposures of 0.01 µg/m³; milling processes mean exposures of 0.02 µg/m³; alloying processes mean exposures of 0.05 µg/m³. The findings show that the airborne beryllium exposures were below the *Permissible Exposure Limit* (PEL) of 2 µg/m³ per working day. This level was set by the U.S. Occupational Safety and Health Administration (OSHA). They are also below the recommended Exposure Limit of 0.5 µg/m³ which was set by the U.S. National Institute for Occupational Safety and Health (NIOSH) and the Permissible Exposure Limit (PEL) of 0.2 µg/m³ set by the State of California.

In the publication of Kent et al. (2007) details on the local exhaust ventilation hoods are given which are needed to assure the exposure levels as described in the study. In the study of Knudson 2008 it is assumed by the author that the recycling operations within the EU control any risk by using state of the art controls and practices. Contrary to this assumption it is reasonable to assume that a large part of the EEE waste streams is treated without application of comparable emission reduction measures (see also chapter 2.7). The study of Kent et al. refers to the recycling of cellular phones. The beryllium content of cellular phones is higher than the average beryllium content of EEE waste. Therefore it can be assumed that during recycling of mixed EEE waste lower beryllium emissions are expected than during recycling of cellular phones.

3.11.6 References

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3.12 Antimony trioxide

3.12.1 Use

Antimony trioxide is a flame retardant synergist that is mainly used in plastics, PVC, rubber and textiles. It is also a catalyst in PET production, an additive in glass manufacture and applied in pigments, paint and ceramics. The use of antimony trioxide as flame retardants in plastics adds up to 9200 tonnes/year (38% of all uses) and as a flame retardant in rubber to

2,200 tonnes/year (9% of all uses). Both entail EEE relevant applications such as in housings for PC, TV and PPC, printed circuit boards, connectors, mouldings, plugs and switches, wires and cables, semiconductors encapsulated, ultra-pure silicon wafers and other small and large household applications. PET films are also used in the electrical segment of its main end-uses, however, this is not considered in the EU RAR. In addition, antimony trioxide is used as a melting agent in glass-ceramic hobs in household appliances also including lamps as well as in glass for TV and PC screens. Antimony trioxide is used in the manufacturing of “Complex Inorganic Coloured Pigments” which are applied to enamels and ceramics to a small extent. These are not considered in detail in the EU RAR.

The amount of antimony trioxide used in EEE that contain flame retardants is difficult to determine as it is only applied as a synergist with halogenated flame retardants. However, estimates exists ranging from 12%–30% for the amount of plastics used in EEE containing flame retardants. The content of antimony trioxide in the final polymer is typically up to 8%, but levels up to 25% are also mentioned. Antimony trioxide is usually used together with additive flame retardants and is mixed into the polymer compounds as a powder additive.

Within the EEE industry there is a trend towards the use of reactive opposed to additive brominated flame retardants.

Table 7 Applications of antimony trioxide and other antimony compounds in EEE (source Antimony Association)

Sb compound	CAS nr	C&L acc. to 67/548	E&E application or component	% Sb ending up in end applic.
Antimony trioxide	1309-64-4	Xn; R40	Flame retardants synergist	1-7w%
			FR wire & cable	1-5w%
			FR housing for TV,PPC etc	3-7w%
			FR connecter & switch etc	3-7w%
			FR semiconducter encapsulant	1-2w%
			melting agent: glass, enamel and ceramic manufacture	0.1-0.8%
Antimony pentoxide	1314-60-9	none	FR for PVC (specially for car interiors)	1-5w%
Antimony Trisulphide	1345-04-6	none	red dye in rubber vulcanisation	
			in combination with ATO: yellow pigment in glass and porcelain	
Antimony Pentasulphide	1315-04-4	none	red dye in rubber vulcanisation	
Sodium antimonate	15432-85-6 or 33908-66-6	Xn; R20/22 and N; R51/53(*)	Flame retardants synergist	5-10w%

			FR connecter & switch etc	5-7w%
	33908-66-6		melting agent: glass manufacture	0.1-0.8%
Antimony metal/alloy	7440-36-0	none	recording media	
			in tin-lead solders (manufacture of circuit boards)	0.12-2.4%
			thermoelectric generator/peltier device	

(*) specific concentration limits apply for preprarations:
$C \geq 25\ \%$: Xn, N; R20/22-51/53
$2{,}5\ \% \leq C < 25\ \%$: Xn; R20/22-52/53
$0{,}25\ \% \leq C < 2{,}5\ \%$: Xn; R20/22

3.12.2 Legislation

- Antimony trioxide shall be classified as “heavy metal” in the classification of hazardous waste, according to the Commission decision 2000/532/EC.
- Maximum air emission limit values for the incineration of waste are established in the Directive 2000/76/EEC of the European parliament and the council.
- Leaching limit values for antimony from waste acceptable at landfills for inert waste are given by the council decision 2003/33/EC (articles 16 of and Annex II to directive 1999/31/EC).
- Maximum specific migration limit of antimony trioxide from plastics used in contact with foodstuffs is given by Commission Directive 2002/72/EC.
- Maximum level of the element antimony in water intended for human consumption is established by the Council Directive 98/83/EC on the quality of water for human consumption.
- With respect to the safety of toys, a maximum level of bioavailability from the application of toys for antimony and other elements is given by the Council Directive 88/378/EEC in 1888. Related definitions and the standard EN 71 are discussed.
- Occupational exposure limits of 0.5 mg/m^3 antimony trioxide on average have been established in several EU countries

3.12.3 Classification

Antimony trioxide is classified according to ANNEX I to Directive 67/548/EEC:

Human health	Xn: - harmful R40: - limited evidence of carcinogenic effect Carcinogen category 3[31]

Endocrine disruption

There is no categorisation according to the EDS database of the EU. It can be concluded that antimony trioxide is not a PBT substance,

PBT and vPvB evaluation

There is no reliable conclusion regarding bioaccumulation, since there is uncertainty in the BCF values. It is not toxic. No statement about persistence is made in the EU RAR.

SVHC

No substance of very high concern.

3.12.4 Risk assessment

Environment

Exposure

The production of antimony trioxide generates mainly emission releases to the air and comparably insignificant emissions to the water.

Use as flame retardant in plastics and rubber

With respect to the use of antimony trioxide as flame retardant in plastics and rubber including the manufacture and uses of EEE, the emission releases are likely to be significantly higher in an earlier stage where antimony trioxide is handled as powder relative to later stages. The forming of the polymer is in partially closed systems and is kept short in time to avoid that the material degrades under the high temperatures that are necessary during the formation. With respect to the polymer processing, it is distinguished between the releases during formulation and conversion. The former causes very high emissions into industrial urban soil followed by wastewater. Much less emissions are released into the air. Most of the conversion is done in a closed system and a smaller fraction is converted in

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[31] Substances and preparations of concern for humans because of the possible CMR effects but for which there is not enough information available to classify these substances and preparations as a category 2 (suspected CMR).

partially closed systems. Moreover, antimony trioxide is non-volatile during the processes. Emission releases to wastewater and into industrial urban soil, but none into the air are calculated by EUSES. During service life only emission releases to surface water are estimated. No specific emission releases of EEE relevant applications are pointed out.

Use in glass

During the formulation emission release to air and industrial urban soil and none to water are calculated, whereas the release during industrial use affects air, surface water and industrial urban soil and depicts higher emission releases, especially to industrial urban soil. Emission releases of EEE relevant applications are not pointed out.

The releases during disposal and recovery are summarised in section 3.12.5.

Apart from emission releases during the production, processing and use of antimony trioxide, unintentional sources should also be taken into account. Possible sources are, for example, the processing of ores and metals where antimony compounds are often found as well as the subsequent metal production. There is also antimony in coal which may be released during the coal combustion.

Risk characterisation

Since all the risk characterization ratios of all EEE relevant processes and uses for the risk to surface water, sediment, wastewater treatment plants, atmosphere, the terrestrial and the marine compartment as well as secondary poisoning are below one for both regional and local sources, no additional information and/or testing and risk reduction measures beyond those already being applied are necessary. Only for the sediment related generic scenarios of an antimony trioxide production site and the formulation and application of flame retardant textile back-coating require limited risk taking the risk reduction measures already being applied into account. This latter conclusion is also drawn for the application of textile back-coating generic site, with respect to marine water and for the formulation and application of flame retardant back-coating, concerning marine sediment. It is mentioned in the EU RAR that uncertainties in the estimates remain because default values are also applied in the scenarios due to a lack of information.

Monitoring

Information on the concentrations of antimony found in aquatic biota is scarce, nonetheless, concentrations of antimony have been found in livers of pikes and perch downstream a glass manufacturer, in livers of freshwater bream from an urban industrialized region and in fresh fish from a lake free of any industries and from a lake in a highly industrialized area.

Concentrations of antimony in terrestrial biota have been found in invertebrates, especially in earthworm, close to an antimony smelter and in mammals including deer close to an urban industrialized area and to an agrarian region as well as shrews, voles, and rabbits close to antimony smelter and in a control site. In addition, measurements of plants and one study with birds show concentrations of antimony.

With respect to marine biota, antimony has been detected in some monitoring studies. For example, relatively high concentrations of antimony have been measured in tissues of finfish, Mollusca, and crustacean taken from the coastal United States, including Alaska and Hawaii.

Concerning the comparison of measured and predicted levels, however, there maybe some over- or underestimations of the predicted PECs, but it is difficult to compare several measurements with the predictions of the sites investigated in the EU RAR.

Human health

The human health part of the EU Risk Assessment Report of Antimony trioxide has not yet been published at the time of preparation of the present report because the Draft Report has still been under discussion in the Competent Group of Member State experts with the aim of reaching consensus. The International Antimony Association, however, provided a summary of available scientific data on Antimony trioxide (International Antimony Association, 2008). These data are presented below:

Consumer exposure

The exposure to consumers may occur via inhalation and dermal contact, in general. As antimony trioxide in the final product is often encapsulated in the matrix, the only release is by way of wear processes (dry abrasion). A detailed monitoring study on antimony content in household dust has been done in the UK for consumer end products such as EEE. The results show very low antimony levels derived in indoor air indicating that the exposure of consumers to antimony for these applications is minimal.

Risk characterisation

The risk characterization related to workers exposed to antimony trioxide requires limited risk taking the risk reduction measures already being applied into account. There is a concern for pulmonary toxicity and skin irritation. The latter requires classification.

The information on consumer exposure concludes that no additional information and/or testing and risk reduction measures beyond those already being applied are necessary. The same result applies to the exposure via the environment. There is no information on EEE appliances available yet.

3.12.5 Disposal and recycling

In municipal waste the antimony concentration is estimated to be about 10-60ppm, however there are large variations. The concentrations of waste from EEE appliances are reported to be in the range from several hundreds up to thousands ppm. The concentration of the feed stream to waste incinerators and of the ashes from incinerators have been examined by studies finding values of 42 mg Sb/kg on average and 40 ± 27 mg Sb/kg refuse, respectively.

Antimony trioxide is the prevailing oxidic form of antimony relative to other forms such as metallic one and is mainly applied in products with limited recyclability such as flame-retardant plastics. The use of antimony in the production of flame retardants is estimated to be more than half of all applications. The antimony measured in the municipal solid waste, therefore, has mainly antimony trioxide origin.

Antimony trioxide is mainly disposed of to a landfill or incinerated. The share of each waste handling technique is not known. The impact of antimony trioxide on the recyclability of WEEE in thermal processes is not exactly clear. Discussions indicate that the recovery of antimony in one type of thermal process may be possible, but that too much antimony might cause process problems in other types of thermal processes.

Limited data suggests about one fourth of the municipal solid waste is incinerated and the remaining part disposed of to a landfill. These shares are not applied in the scenarios of incineration and landfilling. The incineration process generates various outputs such as immediate emissions, stack emissions (flue gas) and wastewater, as well as delayed emissions via disposal and/or re-use, fly ash, bottom ash and slag. The distribution of these outputs depends on the physical-chemical properties, the gas cleaning technology and the operation and maintenance conditions.

In the scenario of 100% incineration of municipal solid waste and an average antimony concentration of 40 ppm, the calculated emission factor at incineration is 0.1%, the emissions to the air are 4.5 tonnes Sb/year and 4477 tonnes Sb/year of ashes are produced. Concerning emissions to water, they result essentially from discharge of wastewater from incineration plants with wet flue gas cleaning systems. Antimony in the influent incinerator wastewater is withdrawn as sludge and the other part stays in the wastewater and will be released to the Wastewater treatment plant. Calculated emissions to wastewater are 5.4 tonnes Sb/year and to sludge 8.1 tonnes Sb/year. However, incinerators with wet scrubber generate lower emissions to air.

Only bottom and fly ash of the delayed emissions from incinerator residuals are considered. Leaching of antimony in the fresh ashes is not that high, however, the leachate of antimony increases during storage when the ph value drops. Attempts to reduce the leakage of antimony in grate ashes are difficult. Therefore, the only solution is to reduce the amount of antimony that results in bottom ashes. No calculated data on emissions are available.

Disposal of municipal solid waste to landfills can result in the generation of landfill gasses and in the leaching of contaminants. Emissions are difficult to quantify since short term and long term impacts occur. Leachate is produced due to the weight of the waste and the compaction as well as the percolation of water through a landfill that is mainly due to percolation. Based on analysed leachates from landfills and a few assumptions, the scenario of 100% landfilling of municipal solid waste generates fugitive emissions of 47 kg Sb/year to each, surface water and groundwater as well as 378 kg Sb/year to wastewater.

3.12.6 References

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- EU Risk Assessment Report Diantimony trioxide, Draft Report (2008)
- International Antimony Association (2008), Summary of currently available scientific data on diantimony trioxide, Background: Risk assessment of diantimony trioxide.

3.13 Bisphenol-A

3.13.1 Use

Bisphenol-A is mainly used for polycarbonate production, epoxy resin production and PVC production and processing. The total consumption of bisphenol-A in Western Europe amounts to 1,149,870 tonnes/year in 2005/2006. Polycarbonates, epoxy resins and flexible PVC are partly used for EEE relevant applications.

Use as polycarbonates

- Total consumption of bisphenol-A amounts to 865,000 tonnes/year in Western Europe;
- Use of the polycarbonates produced from bisphenol-A (typically used in functional parts in long life applications; use periods 5-20 years) that is relevant for electrical and electronic applications:
  - in functional parts in the electric / electronic industry such as: alarm devices, car telephone, mobile phone housings, soil sores, displays, computer parts, household electronic equipment, lamp fittings, power plugs;
  - in inside lights in the automotive industry;
  - as modified high heat resistant copolycarbonates of bisphenol-A used mainly in the automotive and electric/ electronic industry.

Use as epoxy resins

- Total consumption of bisphenol-A amounts to 191,520 tonnes/year in Western Europe;
- Bisphenol-A derived epoxy resins are used in electrical laminates and electrical applications due to superior electrical properties.

Use as (flexible) PVC

- Total consumption of bisphenol-A in PVC amounts to 1800 tonnes/year in Western Europe;
- Incorporation of bisphenol-A into additive package (450 tonnes/year); no information on the end use of these additive package;
- Use of bisphenol-A as an antioxidant in the production of plasticisers used in PVC processing (900 tonnes/year): Flexible PVC is used for electrical applications (53,900 tonnes/year based upon UK data in the UCD plastics additives); all plasticisers which contain bisphenol-A as an antioxidant are used in roofing and cabling with the majority going into the insulation and sheathing of electrical cables.

Tetrabromobisphenol-A

- As bisphenol-A can be used in the production of TBBPA a possible formation of bisphenol-A from a breakdown of TBBPA should be considered. TBBPA is no longer produced in the EU and, therefore, a risk assessment of bisphenol-A in the manufacture of TBBPA is not included in the EU RAR.

Modified polyamide

- Production of modified polyamide amounts to 150 tonnes/year;
- Bisphenol-A serves as an additive (average concentration of less than 8%) that is tightly bound to the polar polyamide matrix;
- use for finished parts with improved dimensional stability mainly in electrotechnical applications.

Alkoxylated bisphenol-A

- Total use amounts to 2,020 tonnes/year in the EU;
- Alkoxylated bisphenol-A functions as an intermediate for epoxy resins;
- Alkoxylated bisphenol-A is not further considered in the EU RAR because its emission releases are assumed to be negligible.

3.13.2 Current legislation

- No environmental legislation referring to bisphenol-A is known.
- Only measure is the specific migration limit to protect consumers. This prescribes a limit of 3 mg bisphenol-A per kg food.
- An Indicative Occupational Exposure Limit Value for bisphenol-A of 10 mg/m³ has been recommended by SCOEL in 2004 which is supposed to be included in a forthcoming IOELV Directive.

3.13.3 Classification

The provisional agreement on the classification for bisphenol-A is as follows:

Human health	Repr. Cat. 3; R62: Possible risk of impaired fertility Xi: irritant R37-41; R43: - Irritating to respiratory system - Risk of serious damage to eyes - May cause sensitisation by skin contact

Endocrine disruption

According to the EDS database of the EU, bisphenol-A is assigned Cat 1. This implies that at least one in-vivo study provides clear evidence for endocrine disruption in an intact organism.

PBT and vPvB evaluation

As bisphenol-A is readily biodegradable in fresh surface waters and soils it is not persistent and does not meet the P criterion. The values of BCF are well below the threshold of bioaccumulation, and, therefore, bisphenol-A does not meet the B criterion. Bisphenol-A, however, shows toxic behaviour.

Therefore, bisphenol-A does not fulfil the PBT criterion, but it is toxic.

SVHC

Bisphenol-A is a substance of very high concern as defined by REACH. This classification is based on fact that Bisphenol-A has endocrine disrupting properties (Cat 1).

3.13.4 Risk assessment

Environment

Exposure

The production of bisphenol-A releases emissions into the air and into receiving waters. Further life cycle stages are investigated separately for the main EEE relevant uses.

Polycarbonates

Emission releases of bisphenol-A during production are shown by one plant that ceased production in 2000. Emission releases to the air added up to 144.5 kg/year and into the water 202.3 kg/year. During processing no volatile loss that may evolve from polymers has been detected. The low residual level, however, depends on proper processing implying the absence of water and reasonable processing temperatures. Concerning the life cycle stage of different uses, migration should be considered. Since residual bisphenol-A within polycarbonates is retained very effectively in the polymer matrix, the extractability by aqueous, alcohol or fat-containing media is very low. Specific exposure information of EEE relevant applications and further life cycle stages is not referred to in the EU RAR.

Epoxy resin

Environmental exposure levels vary, according to information of site specific emission releases of bisphenol-A. In the case of closed systems no exposure is reported. At some sites emission release in the effluent and into the air are determined. With respect to EEE applications of epoxy resins the potential release is low. The residual monomer content of bisphenol-A in the epoxy resin as produced is a maximum of 1,000 ppm. Further reaction of the residual bisphenol-A will occur when the product is used. For food contact uses a specific migration limit is established (see 3.13.2). No further information of other life cycle stages relevant for EEE is reported.

PVC

The use as an anti-oxidant in PVC processing and in the production of plasticisers used for PVC processing, the preparation of additive packages for PVC production and the use as a plasticiser in PVC processing generate losses to the wastewater during raw material handling, compounding and conversion. With respect to the production of PVC additive packages containing bisphenol-A, two sampling exercises derived emissions from all sources to an off-site treatment plant, from all sources after on-site treatment to surface water and releases in rainwater run-off. With respect to the use as a plasticiser a case scenario of processing all flexible PVC for electrical applications at one site estimates losses to the wastewater during raw material handling, compounding and conversion (total continental loss:126 kg/year). During the service life of insulation and sheathing of electrical cables losses to the air, surface water and soil of bisphenol-A are derived from the assessments of phthalates. Similar losses are assumed to be found for the other areas of use for bisphenol-A in PVC.

With respect to the disposal of waste, leaching of bisphenol-A from materials disposed of to landfills has been measured. However, the significance of leachate containing bisphenol-A as well as the exact source material are unknown.

Tetrabromobisphenol-A

TBBPA can degrade to give bisphenol-A under certain anaerobic conditions in marine or saline sediments, freshwater sediments and anaerobic sewage sludge and possibly other anaerobic systems. Calculations done by EURAS (2006) estimate, for example, for TBBPA as a reactive flame retardant used in the processing of epoxy resins concentrations of bisphenol-A in sediment of (1.23–1.7) x 10^{-6} mg/kg wet wt. if the concentrations of TBBPA in sediment are (2.7–4.9) x 10^{-3} mg/kg wet wt.

Modified polyamide

The production of modified polyamide is done in a closed system. No separate emission releases during the production of modified polyamide are reported, only combined emission within the bisphenol-A production.

Risk characterisation

The current risk ratios are all below one for any life cycle stage for the freshwater and marine compartment. For the freshwater and marine compartment further information and/or testing is still necessary due to the concern caused by the potential effects of bisphenol-A on snails that the $\text{PNEC}_{\text{water}}$ and $\text{PNEC}_{\text{marine water}}$ may be too high. An additional study has been initiated testing this effect on snails. The conclusion of no need for further testing and/or information applies to the potential risk in the sediment. Here, the scenarios for TBBPA degradation give PEC/PNEC ratios below one. For the terrestrial compartment and secondary poisoning no information and/or testing or risk reduction measures beyond those which are being applied already are necessary.

Monitoring

Several monitoring studies were completed to measure bisphenol-A concentrations in water and sediment. A summary of all these data gives a concentration mean of 0.13µg/l in freshwater, 60 ng/g dw in freshwater sediment, 0.017 µg/l in marine water and 75 ng/g dw in marine sediment. Since the calculated levels of concentrations of bisphenol-A in sediment and water are comparable with the measured values, the risk assessment is based on calculated values.

There are a few monitoring studies on levels of bisphenol-A in biota. Concentrations of bisphenol-A in fish have been found, for example in freshwater in Norway.

Human health

Exposure

The exposure is likely to be negligible in many cases as the residual bisphenol-A in epoxy resins and polycarbonate is low.

Occupational exposure

During bisphenol-A manufacturing the highest inhalation exposures relative to the other manufactures such as the manufacture of polycarbonates were reported. Bag filling and maintenance activities caused the highest estimates for dermal exposure.

Polycarbonate

There is little or no opportunity for bisphenol-A exposure during the manufacture of polycarbonate as it is produced in a closed system. There is a maximum of 100 ppm residual bisphenol-A within the polymer which is bound into the matrix of the polymer. The production of polycarbonate may be critical if it is chopped into granulates, but still results in a low exposure.

During the manufacture of articles from polycarbonate exposure to bisphenol-A is not possible because residual bisphenol-A retains within the polymer matrix. As the polycarbonate would not be heated more than for extrusion, the release of residual bisphenol-A is unlikely or very low.

Epoxy resins

Residual amounts of bisphenol-A depend on the fact whether epoxy resin is a liquid or a solid. 300 ppm has been applied as representative of residual bisphenol-A in epoxy resin. There is no significant exposure to bisphenol-A during the manufacture of liquid epoxy resin-based paints since residual bisphenol-A (10 ppm) is mostly retained within the resin matrix. Critical points of possible exposure are during delivery, quality control sampling and, which both is seldom, changing of filter socks and calibration of the weigh vessels. However, there are some indications provided by the industry that this exposure may be negligible.

PVC

No separate exposure levels available. Therefore, data of another sort of manufacture is taken as it is similar. However, the use of bisphenol-A in PVC is being phased out.

Consumer exposure

Exposure to consumers may only occur if residual monomer in the polymer matrix becomes available or where a breakdown of polymer arises to produce additional monomer. Increasing amounts of bisphenol-A may be available under certain conditions such as elevated temperature or extreme pH resulting possibly in a hydrolysis of the polymer and, therefore, in the regeneration of bisphenol-A. The highest exposure occurs if the products are in direct contact with foodstuff. EEE relevant products such as epoxy-based surface coatings and adhesives mainly affect humans via dermal contact. In 2-pack adhesives residual bisphenol-A content is less than 1 ppm.

Indirect exposure via the environment

Human exposure may occur via drinking water, consumption of fish, plant roots, plant leaves, milk, meat and via air. The main route of exposure from environmental sources is the oral one.

Combining possible exposures, the highest levels of exposure are for someone who is exposed via the environment near to a bisphenol-A plant and, in addition, exposed via food contact materials.

Risk characterisation

With respect to workers and consumers, there are no concerns for acute toxicity, skin irritation, respiratory sensitisation, mutagenicity and carcinogenicity. For repeated dose systematic effects and for reproductive toxicity during the manufacture of bisphenol-A and the manufacture of epoxy resins limit risk is needed taking the already applied risk reduction measures into account. The same conclusion applies to skin sensitisation in all occupational exposure scenarios in the case of possible skin contact with high concentrations of bisphenol-A. With respect to consumer exposure, no additional testing and/or information or risk reduction measures beyond those already being applied is necessary. The same conclusion applies to human exposure via the environment. There is no detailed information given on the risk characterization of EEE appliances.

3.13.5 Disposal and recycling

Concerning polycarbonates, waste material may be directly processed into articles of inferior properties or applied as a secondary raw material added to virgin material for the production of recycled grades. The remaining polycarbonates that are not recycled are mainly put on landfills or disposed of to municipal waste incineration. Epoxy resins are assumed to be not recycled, but disposed of to landfills or municipal waste incineration. By incineration any free bisphenol-A in the product will be destroyed. There is no further information about this process in the EU RAR.

Soil may be exposed to bisphenol-A via sludge disposal. Sludge generated by wastewater treatment plants can be disposed of to landfills or incinerated or applied to agriculture land. The degradation of TBBPA, for example, during sludge digestion resulted in no risks for the environment.

Leaching of bisphenol-A from materials disposed of to landfills has been measured. However, the significance of leachate containing bisphenol-A as well as the exact source material are unknown. The EU RAR does not give further information on disposal and recycling procedures and relevant emission releases. Therefore, further information and testing, especially with respect to the disposal and recycling of EEE containing bisphenol-A should be done.

3.13.6 References

- Ackerman, F. & Massey, R. (2003): The Economics of Phasing out PVC, Global Development and Environment Institute (GDAE), Tufts University.
- European Union Risk Assessment Report 4,4'-isopropylidenediphenol (bisphenol-A); Final Report (2003).
- Møller, L., Helweg, C., Pratt, C. H., Worup, A. & Skak, C. (2004): Evaluation of Alternatives for Compounds under Risk Assessment in the EU, Bisphenol A, Danish Environmental Protection Agency, Internet publication at http://www.miljøstyrelsen.dk/udgiv/publications/2004/87-7614-181-0/pdf/87-7614-182-9.pdf.

4 Candidates for potential inclusion in RoHS

Under consideration of the selection criteria specified in section 2.3 so called high priority substances have been identified (Table 2). These substances have further been evaluated by analysis of available risk assessment reports and other relevant information (see section 3). Special attention was laid on the possible exposure of environment and human health during the use phase and the recycling/disposal phase of electrical and electronic equipment containing the hazardous substances. For most of the hazardous substances, however, the risk assessment reports contain only limited information on the use phase and the end-of-life management of electrical and electronic equipment.

In addition to calculated exposure data, monitoring data of measured concentrations of hazardous substances in biota and environmental media such as water and sediment were evaluated and taken into consideration for the proposal of candidate substances. Some Member States support the position against the background of the precautionary principle substances of very high concern should not be released into the environment at all.

Further to the exposure situation, the relevance of EEE with regard to the total consumption of the substances as well as the availability of substitutes has been taken into account.

Based on the results of this analysis, candidate substances for potential inclusion in RoHS are proposed. These substances constitute significant health and environmental risks when used in electrical and electronic equipment (Table 8).

Arguments in favour of a possible inclusion of the candidate substances into RoHS are discussed below. In chapter 5, information on substitutes to the proposed candidate substances are presented (as far as information is publicly available). In chapter 6 policy options for each candidate substance are proposed.

Table 8 List of candidates for potential inclusion in RoHS

ID	Substance name	CAS-No.	Hazard classification	Arguments in favour of inclusion into RoHS
1	Tetrabromo bisphenol A (TBBP-A)	79-94-7	N; R50/53[32]	- Use as additive flame retardant may result in risks for the environmental compartments water, sediment and agricultural soil - For the use as additive flame retardant in ABC sufficient halogen-free alternatives are available - Monitoring data show detections of TBBP-A in biota remote areas - Risk of formation of PBDDs and PBDFs - Epoxy resins used in PCBs cannot be recycled by remelting
2	Hexabromocyclododecane (HBCDD)	25637-99-4	Proposed classification: N; R50-53; PBT	- Substance of very high concern: PBT substance - Used as additive flame retardant in HIPS; HBCDD may leach out of polymer matrix - For the use as additive flame retardant in HIPS sufficient halogen-free alternatives available - Monitoring data show detections of HBCDD in rural and remote areas; several studies report increasing concentrations of HBCDD in biota - Risk of formation of PBDDs and PBDFs
3	Bis (2-ethylhexyl) phthalate (DEHP)[33]	117-81-7	Repr. Cat. 2; R60-61	- Substances of very high concern: reprotoxic Cat. 2 and endocrine disruptors Cat. 1 - Phthalates are not chemically bound to the plastic, but dispersed in the matrix. Thus, they may be released out of the material over time leading to emissions to the environment.
4	Butylbenzylphthalate (BBP)[34]	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62	

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[32] TBBP-A is included in the OSPAR List of Chemicals for Priority Action (Update 2007)

[33] DEHP is a Water Framework Directive Priority Substance, and is also subject to a comprehensive risk assessment under Council Regulation 793/93/EEC. Risk management proposals are being prepared by the Swedish rapporteur; Restricted for toys by Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC.

ID	Substance name	CAS-No.	Hazard classification	Arguments in favour of inclusion into RoHS
			N; R50-53	- Monitoring data indicate an ubiquitous presence of DEHP, BBP and DBP in biota and environmental compartments - Non-phthalate plasticisers and alternatives to PVC are available
5	Dibutylphthalate (DBP)[35]	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	
6	Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	currently not classified according to 67/548; proposed classification: N; R50/53 Endocrine disruptor, Cat 1 (according to EDS database)	- Substances of very high concern: endocrine disruptors Cat. 1 - MCCPs are persistent, have a high potential for bioaccumulation in fish indicated by high fish bio-concentration factors and are very toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment - Proposed to be classified with the risk phrase “May cause harm to breast fed babies” - MCCP have been found in the food chain, including in fish, in cow milk and in breast milk - Monitoring data from Norway show widespread occurrence in the environment - Risk of formation of PBDDs and PBDFs
7	Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	Carc. Cat. 3; R40 N; R50-53	- Substances of very high concern: endocrine disruptors (Cat. 1) & PBT substance - included in the priority list of Hazardous Substance of the European Water Framework Directive - included in the POP convention - regulated by Directive 76/769/EC and REACH Annex XVII (item 27) - Monitoring studies identify SCCP as body burden in biota - Risk of formation of PBDDs and PBDFs

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[34] Restricted for use in toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

[35] Restricted for use in toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

ID	Substance name	CAS-No.	Hazard classification	Arguments in favour of inclusion into RoHS
8	Nonylphenol/ Nonylphenol ethoxylates	25154-52-3 9016-45-9	Endocrine disruptor, Cat 1 (according to EDS database)	- Substances of very high concern: endocrine disruptors Cat. 1 - Bioaccumulative and very toxic to aquatic organisms - Nonylphenol is included in the priority list of Hazardous Substance of the European Water Framework Directive

4.1 Discussion of proposed candidate substances

4.1.1 TBBP-A

TBBP-A is not classified according to Directive 67/548/EC. Furthermore, it does not fulfil the criteria for PBT or vPvB. However, TBBP-A is considered to be persistent (P) or potentially very persistent (vP).

The possible effects of TBBP-A on the endocrine system are subject to current research in the EU FIRE project[36]. The FIRE project (Flame retardants Integrated Risk assessment for Endocrine effects) supported by the European Commission investigates the possible emerging health risk for humans and wildlife of BFRs (including TBBP-A) by endocrine related mechanisms. Final results of this study are not yet available.

A final conclusion whether or not TBBP-A fulfils the REACH criteria for substances of very high concern (SVHC) can therefore not yet been drawn.

Available monitoring data suggest that the substance is present at low levels in the tissues of a wide variety of marine organisms including some top predators, predatory birds from remote areas (e.g. northern and Arctic regions of Norway) and human breast milk from remote areas (e.g. the Faro Islands).

According to the EU Risk Assessment Report the use of TBBP-A as additive flame retardant in ABS may result in risks for the environmental compartments water, sediment and agricultural soil (section 3.1). Additive TBBP-A does not react chemically with the other components of the polymer and therefore may leach or volatilise out of the polymer matrix over the lifetime of the products. Recycling of plastics containing additive flame retardants is not routinely carried out in the EU. The plastics containing additive TBBP-A will usually be disposed of either to landfill or by incineration. When plastic containing TBBP-A, either as an additive or as residual monomer, is disposed of to landfill, in theory it could volatilise to the atmosphere or leach out of the plastic into groundwater. It is not currently possible to quantify the actual releases of TBBP-A from landfills. In case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators there is a risk of formation of PBDDs and PBDFs, both for the use of TBBP-A as additive as well as reactive flame retardant. This needs to be considered particularly with regard to shipment of used and obsolete electrical and electronic equipment for refurbishment and reuse to African and Asian destinations where recycling practices and subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards.

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[36] FIRE (Flame retardants Integrated Risk assessment for Endocrine effects): Risk Assessment of Brominated Flame Retardants as Suspected Endocrine Disrupters for Human and Wildlife Health

The residues are mostly disposed on uncontrolled dump sites, which are set on fire regularly (see section 2.7).

For the use as additive flame retardant in ABC sufficient halogen-free alternatives are available (5.1.1), thus a phase-out of TBBP-A would be possible at a rather short notice.

Due to the fact that TBBP-A is persistent and is detected in the environment and biota even in remote areas, it is proposed that the phase out of TBBP-A (especially as additive flame retardant) should have priority over selective risk management measure to guarantee a reduced emission of TBBP-A in order to fulfil the precautionary principle.

4.1.2 HBCDD

HBCDD is fairly persistent, bioaccumulates significantly and fulfils the criterion for a toxic substance. Overall, HBCDD fulfils the PBT criteria of the Technical Guidance Document. Consequently, HBCDD is considered as a substance of very high concern as defined by REACH.

Available monitoring studies prove that HBCDD levels are found in European fish, marine mammals especially seal and porpoise, marine birds eggs and further biota such as freshwater fish and terrestrial birds. In remote areas such as Sweden and Finland, far from the potential sources, HBCDD levels have been measured. Therefore, HBCDD is assumed to undergo long-range atmospheric transport. In addition, many studies suggest an increase in the concentration of HBCDD in biota over time.

HBCDD is used as additive flame retardant mainly in building constructions and in the textile industries. About 2% of the total use of HBCDD is in high impact polystyrenes (HIPS) used in electrical and electronic parts like electric housings for VCR, distribution boxes for electrical lines or video cassette housings. The HBCDD content in HIPS is between 5 or 7 % (w/w). Despite the limited uses in EEE, the total use of HBCDD in EEE relevant applications adds up to more than 210 tonnes per year in the EU.

Additive flame retardants do not react chemically with the other components of the polymer and may therefore leach or volatilise out of the polymer matrix over the lifetime of the products. No specific information is given in the Risk Assessment Report on the disposal and recycling of products relevant for EEE. However, as for TBBP-A, it can be assumed that recycling of plastics containing additive flame retardants is not routinely carried out in the EU. The plastics containing HBCDD will usually be disposed of either to landfill or by incineration. When plastic containing HBCDD is disposed of to landfill, in theory it could volatilise to the atmosphere or leach out of the plastic into groundwater. In case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators there is a risk of formation of PBDDs and PBDFs. This needs to be considered particularly with regard to shipment of used and obsolete electric and electronic equipment for refurbishment and reuse to African and Asian destinations where recycling practices and subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards. The residues are mostly disposed on uncontrolled dump sites, which are set on fire regularly (see section 2.7).

For the use of HBCDD as additive flame retardant in HIPS, several halogen-free alternatives (halogen-free plastics and flame retardants for housings) are available (section 5.1.2); thus a phase-out of HBCDD would be possible at a rather short notice.

Due to the fact that HBCDD is fairly persistent, bioaccumulative and toxic, and is detected in the environment and biota even in remote areas, it is proposed that the phase out of HBCDD should have priority over selective risk management measure to guarantee a reduced emission of HBCDD in order to fulfil the precautionary principle.

4.1.3 DEHP, BBP and DBP

The three phthalates DEHP, BBP and DBP meet the criteria for classification as toxic for reproduction category 2 in accordance with Directive 67/548/EE. They have Category 1 endocrine disrupting properties meaning that at least one in-vivo study provided evidence of endocrine disruption in an intact organism. DEHP, BBP and DBP are consequently substances of very high concern as defined by REACH.

Phthalates are mainly used as plasticisers (or softeners) in plastics, especially in flexible PVC (e.g. in cables and other flexible components). In flexible PVC products the typical phthalate content ranges from 35–45%. Phthalates that are incorporated into plastic materials are not chemically bound to the plastic, but dispersed in the matrix. Thus, they may be released out of the material over time. This can result in substantial losses to the environment during the lifetime of products and during their disposal. Leaching out from certain applications and transportation in the air seems to be the major routes of entering the environment. The annual use of DEHP in PVC used for cables & wires was approximately 80,920 tonnes in 1997. The use of DEHP has decreased, however, significantly during the last years in favour of DINP and DIDP.

Monitoring data in the aquatic compartment show that DEHP is ubiquitous in the environmental compartments; however the monitoring focused on urban and industrial areas. DEHP is measured in all biota samples investigated. The general exposure via the environment and the infant exposure via breast milk are considered to pose a risk for children. Monitoring data for DBP and BBP in environmental compartments and biota are quite scarce but also indicate ubiquitous presence of these phthalates.

Non-phthalate plasticisers are available e.g adipates, citrates, (organo)phosphates and trimelliate (section 5.1.3). Some of the alternative plasticisers do show advantages from an environmental point of view compared to phthalates. Further test, however, are considered necessary. The main application of phthalates in EEE is their use in PVC cables. For cables, there are PVC-free materials from PE (Polyethylene) or EVA (Ethyl-Vinylacetate-Copolymere) available that are technically suited for different voltages but more expensive then PVC cables; thus a phase-out of DEHP, BBP and DBP would be possible at a rather short notice.

Due to the fact that DEHP, BBP and DBP as reprotoxic and endocrine disruptive substances are found as body burden in humans and biota, it is proposed that the phase out of these three phthalates should have priority over selective risk management measure. This guarantees more effectively a reduced emission of the three phthalates. The option is a consequence of the precautionary principle which should be applied for substances of very high concern.

4.1.4 MCCP

MCCPs are persistent, bioconcentrate in fish, are very toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment. Further testing is underway to examine the PBT properties of some of the components. Furthermore, they have Category 1 endocrine disrupting properties meaning that at least one in-vivo study provided evidence of endocrine disruption in an intact organism. Overall, MCCPs are considered as substances of very high concern as defined by REACH.

MCCP have been found in the food chain, including in fish, in cow milk and in breast milk. It is proposed to classify MCCPs with the risk phrase “May cause harm to breast fed babies”. Monitoring data from Norway show widespread occurrence in the environment. Apart from biota, MCCPs have been detected in environmental media such as sediment and water.

The main uses of MCCPs are as secondary plasticisers / softener and as flame retardant in PVC, in rubber and in polymers others than PVC. PVC production accounts for about 80% of the MCCP use. In addition, MCCPs are used as lubricants and additives in metal working/cutting. EEE relevant appliances of MCCP are in flexible PVC such as in cable sheathing and insulation. The exact amounts of EEE relevant uses of MCCP are not given in the EU RAR.

Since MCCPs are not changed during their lifecycle, ultimately all the chlorinated paraffins used in products will be disposed of at the end of life of the product. Disposal by landfill or incineration is likely to be the ultimate destination of much of the chlorinated paraffin. The amount of MCCPs disposed of to landfill and incineration each year is estimated about 60,000 t. The vast majority of this amount is likely to be present in PVC articles. In landfills, chlorinated paraffins may be expected to be relatively stable for a number of years and so could be subject to leaching or volatilisation from the landfill.

During incineration processes, chlorinated paraffins can basically be a source of chlorine then leading to the formation of polychlorinated dioxins and furans. Besides unsaturated hydrocarbon products, including aromatic products such as polychlorinated biphenyls and polychlorinated naphtalenes can also be formed under certain circumstances, such as under heat or in contact with alkaline substances. This needs to be considered particularly with regard to shipment of used and obsolete electrical and electronic equipment for refurbishment and reuse to African and Asian destinations where recycling practices and subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards. The residues are mostly disposed on uncontrolled dump sites, which are set on fire regularly (see section 2.7).

Due to the fact that MCCPs are persistent, very toxic to aquatic organisms and are endocrine disruptors that bioconcentrate in the (fish) food chain, it is proposed that the phase out of MCCPs should have priority over selective risk management measure to guarantee a reduced emission of MCCPs in order to fulfil the precautionary principle.

4.1.5 Short-chained chlorinated paraffins SCCPs

During the stakeholder consultation on hazardous substances not regulated by RoHS contradictory information have been provided with regard to uses of SCCPs in EEE. According to most manufacturers SCCPs are not in common use in EEE. They were only used in the production process of EEE e.g. for metal working like molding, etc., but were not present in the final products. The use of SCCPs in metal working has meanwhile been restricted by Council Directive 76/769/EC and by REACH Annex XVII (item 27).

One manufacturer, however, stated that SCCPs are still used in power supplies, in industrial and commercial sensors (coin sensors, paper sensors, etc.) and in industrial flash lamps as well as in photonics lamps. The exact function of SCCPs has not been specified. Further discussions with the respective stakeholders are necessary in order to clarify whether or not SCCPs are still used in EEE.

SCCPs are persistent, bioaccumulative and toxic substances fulfilling all PBT criteria. Furthermore, they have Category 1 endocrine disrupting properties meaning that at least one in-vivo study provided evidence of endocrine disruption in an intact organism. Overall, SCCPs are considered as substances of very high concern as defined by REACH.

SCCPs are included in the priority list of Hazardous Substance of the European Water Framework Directive, are POP[37] candidates and are regulated by 76/769/EC and REACH Annex XVII (item 27): They may not be placed on the market for use as substances or as constituents of other substances or preparations in concentrations higher than 1%:

- in metal working;
- for fat liquoring of leather.

Monitoring studies on biota usually report the level of total chlorinated paraffins. A few studies report measured levels of SCCPs in food, fish and marine animals and mussels. In addition, short and intermediate chain length chlorinated paraffins have been detected in birds, eggs and human foodstuffs in the United Kingdom. SCCPs have also been found in sheep near to a chlorinated production site and in rabbit muscles.

During incineration processes, chlorinated paraffins can basically be a source of chlorine then leading to the formation of polychlorinated dioxins and furans. Besides unsaturated hydrocarbon products, including aromatic products such as polychlorinated biphenyls and polychlorinated naphtalenes can also be formed under certain circumstances, such as under heat or in contact with alkaline substances. This needs to be considered particularly with regard to shipment of used and obsolete electric and electronic equipment for refurbishment and reuse to African and Asian destinations where recycling practices and subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards. The residues are mostly disposed on uncontrolled dump sites, which are set on fire regularly (see section 2.7).

Due to the fact that SCCPs are persistent, bioaccumulative and toxic (PBT) and are endocrine disruptors, it is recommended that the complete phase out of SCCPs should have priority over selective risk management measure to guarantee a reduced emission of SCCPs in order to fulfil the precautionary principle. Therefore, they should be included in RoHS (further information from the manufacturers is necessary in order to clarify whether SCCPs are still used in EEE).

4.1.6 Nonylphenol[38] and nonylphenol ethoxylates

Nonylphenol is used for the production of nonylphenol ethoxylates which are used to a small extent as surfactants in electrical and electronic engineering industry.

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[37] POPs: Persistent Organic Pollutants are chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.

[38] 4-nonylphenol (branched) and nonylphenol.

During the stakeholder consultation on hazardous substances not regulated by RoHS contradictory information have been provided with regard to uses of nonylphenol ethoxylates in EEE. According to most manufacturers nonylphenol ethoxylates are not anymore used in EEE. These surfactants were used in coatings for films in EEE, and in formulations to clean printed circuit boards. However, these applications have been phased out since January 2005 by the restriction specified in Directive 76/769/EEC and item 46 of Annex XVII to REACH.

The following uses are restricted:

- cleaning
- textiles, leather processing,
- emulsifier in agriculture
- metal working
- pulp/paper
- cosmetic + personal care
- co-formulant in pesticides and biocides

One manufacturer, however, stated that nonylphenol ethoxylates are still used in/as adhesives. The exact function of nonylphenol ethoxylates has not been specified. Further discussions with the respective stakeholders are necessary in order to clarify whether or not nonylphenol ethoxylates are still used in EEE.

Due to the fact that nonylphenol and nonylphenol ethoxylates are bioaccumulative and thus may build up in the food chain, are very toxic to aquatic organisms and are endocrine disruptors, it is proposed that the complete phase out of nonylphenol and nonylphenol ethoxylates should have priority over selective risk management measure to guarantee a reduced emission of nonylphenol and nonylphenol ethoxylates in order to fulfil the precautionary principle. A final recommendation on the inclusion of nonylphenol and nonylphenol ethoxylates in RoHS is, however, only possible after further discussions with relevant stakeholders in order to clarify whether or not nonylphenol and nonylphenol ethoxylates are still used in EEE and are present in the final product.

4.1.7 Organochlorine and organobromine compounds

The brominated and chlorinated substances listed in Table 8 may form polybrominated and polychlorinated dioxins and furans in case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators. This risk of formation of dioxins and furans applies, however, not only to the proposed candidate substances in Table 8, but to all organohalogen compounds like brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins, polyvinylchloride (PVC), etc.

Halogenated substances contained in electrical and electronic equipment are ubiquitously distributed around the globe. As discussed in chapter 2.7, there is strong evidence that an significant amount of used and obsolete electrical and electronic equipment is shipped for refurbishment and reuse to African and Asian destinations. A wide range of studies could document the recycling and disposal practices in Asian and African EEE destinations: In China and India, EEE not suitable for refurbishment undergoes so called 'backyard recycling' with the aim to recover plastics, copper, silver and gold with comparably low yields. These recycling practices and the subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards (e.g. open burning of copper wires, treatment of PCBs in open acid baths, uncontrolled incineration of plastics). The residues are disposed on uncontrolled dump sites, which are set on fire regularly. By these practices that are far away from controlled waste disposal practised in Europe there is a high risk of formation of dioxins and furans as well as chloro- and bromobenzenes, PCBs, phthalate esters and other halogenated and non-halogenated compounds. Many of these organic chemicals are highly toxic to humans and have adverse effects to the environment.

The definition of selective risk management measures, e.g. in form of controlled waste disposal, is therefore not sufficient to adequately control these hazardous substances.

In the face of these facts it is proposed that not only TBBP-A, HBCDD, medium and short-chained chlorinated paraffins should be restricted by RoHS, but that all organohalogen compounds including brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins, polyvinylchloride (PVC), etc. should be phased out from electrical and electronic equipment in order to fulfil the precautionary principle.

Several manufacturers of EEE are committed to achieving phase out of brominated flame retardants (BFR) and PVC in all their applications proving that substitution of organohalogen compounds in EEE is possible at least for the majority of applications (Greenpeace 2008).

Possibilities for further specifications of this group will be checked during the preparation of the final version of this report.

4.1.8 Halogenated organic compounds

The brominated and chlorinated substances listed in Table 8 may form polybrominated and polychlorinated dioxins and furans and other hazardous halogenated substances in case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators. This risk applies, however, not only to the proposed candidate substances in Table 8, but to all organohalogen compounds like brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins, halogenated polymers (such as e.g. ethylene-chlortrifluorethylene copolymers, polychlortrichlorethylene (PCTFE), polychloroprene (CR), polyvinylchloride (PVC)).

Halogenated organic compounds contained in electrical and electronic equipment are ubiquitously distributed around the globe. As discussed in chapter 2.7, there is strong evidence that significant amounts of used and obsolete electrical and electronic equipment are shipped for refurbishment and reuse to African and Asian destinations. A wide range of studies could document the recycling and disposal practices in Asian and African EEE destinations: In China and India, EEE not suitable for refurbishment undergoes so called 'backyard recycling' with the aim to recover plastics, copper, silver and gold with comparably low yields. These recycling practices and the subsequent disposal are carried out in open processes without basic forms of environmental and work-safety standards (e.g. open burning of copper wires, treatment of PCBs in open acid baths, uncontrolled incineration of plastics). The residues are disposed on uncontrolled dump sites, which are set on fire regularly. By these practices (that are far away from controlled waste disposal practised in Europe) there is a high risk of formation of dioxins and furans as well as chloro- and bromobenzenes, PCBs, phthalate esters and other halogenated and non-halogenated compounds, due to the presence of halogenated organic compounds in the EEE. Many of these organic chemicals are highly toxic to humans and have adverse effects to the environment.

The definition of selective risk management measures, e.g. in form of controlled waste disposal, is therefore not sufficient to adequately control these hazardous substances.

In the face of these facts it is proposed that not only TBBP-A, HBCDD, medium and short-chained chlorinated paraffins should be restricted by RoHS, but that all organohalogen compounds like brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins and halogenated polymers should be phased out from electrical and electronic equipment in order to fulfil the precautionary principle.

Several manufacturers of EEE are committed to achieving phase out of brominated flame retardants (BFR) and PVC in all their applications proving that substitution of organohalogen compounds in EEE is possible at least for the majority of applications (Greenpeace 2008).

5 Substitution

For the candidate substances listed in Table 8 and their EEE applications, possible available substitutes for the respective use in EEE have been analysed. Publicly available data have been reviewed for this purpose and the possible substitution either through substitutes or alternative materials and/or design changes have been discussed with experts from industry and research institutes.

5.1 Possible substitution of candidate substances

5.1.1 TBBP-A

Substitution of TBBP-A in printed circuit boards

Printed circuit boards are usually made from epoxy resins with glass fibre reinforcement. This type of PCB fulfils the FR-4 classification and is most commonly used in the electronics industry (about 80%).

There are two possible approaches to phase out TBBP-A from PCB:

a) Substitution of TBBP-A by other, non-halogenated flame retardants with epoxy resin as base material:

Reactive flame retardants:

- DOPO (Dihydrooxaphosphaphenantrene) and its derivates which are cyclic hydrogenphosphinates,
- Poly(1,3-phenylene methylphosphonate) which can react into the polymer and act as a curing agent for epoxies. The latter one is recommended in combination with ATH[39] or AOH[40]

Additive flame retardants:

- Metal phosphinates
- Melamine polyphosphate, used in combination with other FRs (e.g. phosphinates, minerals)
- Metal hydroxides e.g. Aluminium Trihydroxide (ATH, Al(OH)3); Alumina monohydrate (AlOOH)

More information on substitution of TBBP-A in PCB is presented in De Boysére (2007), Döring (2007), KEMI (2006a), Morose (2006), UBA (2001b) and UBA (2001c).

b) Use of inherently flame-retardant, halogen-free base materials

- Thermosetting plastics e.g. epoxy-novolac resins. These epoxy-novolac resins need less flame retardants in comparison to the normally used diglycidyl ether of bisphenol-A resins, which makes it easier to achieve the technical requirements with halogen-free flame retardants.
- Thermoplastic resins e.g. PEI (Polyether Imide) and PES (Polyethersulfone).

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[39] ATH: Aluminium-tri-hydroxide

[40] AOH: Aluminium-oxide-hydroxide

> In contrast to common epoxy resins and thermosetting plastics, thermoplastic resins can be recycled. It is disadvantageous with regard to substitution, however, that inherently flame-retardant resins are often more expensive than the common epoxy resins.

It can be summarised that suitable substitutes and alternative materials are available to replace TBBP-A in printed circuit boards.

It has often been claimed that not enough toxicological and environmental data exist to justify a switch from currently used flame retardants to halogen-free materials. For halogen-free flame retardants, no official European risk assessments have been carried out up to now. According to information provided by Döring (2006), most halogen-free flame retardants have an environmentally friendly profile, which means that they pose no harm to the environment and do not bio-accumulate in biota. In addition they have a low (eco)toxicity profile and will eventually mineralize in nature. Due to these characteristics, none of the halogen-free flame retardants are considered to be PBT or vPvB. Environmental and toxicological properties for a number of flame retardants have been summarized in fact sheets that can be downloaded from http://www.halogenfree-flameretardants.com. Manufacturers of flame retardants have started to identify data gaps and commission the necessary tests and studies, because these will also be required by the new European chemicals legislation, REACH (1907/2006/EC). Under REACH not only hazard data, but also data concerning emissions, uses and end of life will be gathered. One company has already commissioned a life cycle emission study (Marzi & Beard 2006).

US-EPA is currently coordinating a research project on Flame Retardants in Printed Circuit Boards (EPA USA, 2006). The goal of this multi-stakeholder partnership is to identify and evaluate commercially available flame retardants and their environmental, human health and safety and environmental fate aspects in FR-4 printed circuit boards. The final report and the publication of results are scheduled for Spring 2008.

Substitution of TBBP-A as additive FR in ABS

No halogen-free flame retardants for ABS are available providing the same properties as TBBP-A. However, a number of other halogen-free plastics and flame retardants for electric enclosures are available on the market:

Electronic enclosures are included in the enclosures of consumer and information technology equipment such as televisions, desktop or notebook computers, monitors, printers, copiers, household appliances, etc. These housings are made of different types of polymer resins such as high impact polystyrene (HIPS), acrylonitrile butadiene styrene copolymers (ABS), polycarbonate / ABS blends (PC/ABS) and polyphenylene oxide / HIPS blends (PPO/HIPS).

International standards provide that the plastic materials used for these housings usually should meet high fire safety standards such as UL 94 V[41,42] or similar flame retardant specification. In general, it is not possible to meet these requirements with the pure polymer resins. Therefore, flame retardants are added to the polymer compound.

The following three phosphorous based flame retardants can be used in combination with PC/ABS and PPE/HIPS blends for electronic enclosures instead of TBBP-A in ABS (Döring, 2007).

- Tri-phenyl phosphate (TPP)
- Resorcinol bis (diphenyl phosphate) (RDP)
- Bis-phenol A bis(diphenyl phosphate) (BDP)

The Danish EPA has assessed the above mentioned halogen-free flame retardants for a range of environmental and human health impacts. The results are summarised in Table 9. Further information on TPP, RDP and BDP are provided in sections 9.6, 9.7, and 9.8 of the Annex, respectively.

ECB (2007) states that for most of the possible substitutes published information on (eco-) toxicological endpoints is not available. It is concluded that given those data gaps, it is not possible at this time to determine with any certainty if the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits.

Table 9 Halogen-free substitutes to TBBP-A

Name	CAS No.	Classification	PBT	CMR
Triphenyl phosphates (TPP)	115-86-6	None	Not considered persistent or bioaccumulative; it is questionable whether TPP meets the T criterion, as the validity of the chronic NOEC values reported are uncertain (ECB, 2007)	There are no studies available from which a conclusion on the carcinogenic potential of triphenyl phosphate can be drawn. However, no mutagenic effect was found in any of the in vitro genotoxicity studies available although the studies included tests with and without metabolic activation. In vivo genotoxicity is not tested. In a well performed and reported study no effects

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[41] Industrial standard measurement of flammability referring to Underwriters Laboratories Inc., and to section 94 of the regulations covering "Tests for Flammability of Plastic Materials for Parts in Devices and Appliances". Materials are tested in a number of different ways to ensure that they pass the UL-94 rating.

[42] The UL 94 V: vertical flame test, V-0 grade is typically required for plastic parts in connectors, switches, and other components in contact with current bearing metal parts of EEE. In the USA, V-0 grade plastics are also required for TV-set enclosures, whereas the European standard has less strict requirements i.e.V-17. However the major European producers today use a higher level of flame-retardancy than required by the European standard.

Name	CAS No.	Classification	PBT	CMR
				on reproduction and no teratogenic potential was found of daily doses up to and including 690 mg/kg bw administered before and during mating and throughout gestation (ECB, 2007).
Resorcinol bis (diphenyl phosphate) (RDP)	57583-54-7	None	Not considered persistent, bioaccumulative or toxic (ECB, 2007)	Not CMR
Bis-phenol A bis (diphenyl phosphate) (BDP)	5945-33-5	None	Not considered bioaccumulative or toxic; persistence unknown (ECB, 2007)	

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5.1.2 HBCDD

HBCDD is used in HIPS for housings of EEE. A substitution of HIPS by non halogen flame retardants is not possible. However, non halogen plastics and non halogen phosphoric flame retardants such as Resorcinol bis (diphenyl phosphate) (RDP) or Bis-phenol A bis(diphenyl phosphate) (BDP) with plastic mixtures such as polycarbonate (PC), polycarbonate / ABS blends (PC/ABS) or polyphenylene oxide / HIPS blends (PPO/HIPS) exist that fulfil the level of flame retardant for equipment housings. A complete substitution is thus possible (ECB 2007, EPA Denmark 2006a, KEMI 2005, Lovell Center 2005 und UBA 2001). See also substitution possibilities for TBBP-A (section 5.1.1).

5.1.3 Phthalates

Phthalates are mainly used as plasticizers (or softeners) in plastics, especially in flexible PVC (e.g. in cables and other flexible components). Alternative plasticizers in PVC are adipates (esters of adipic acids: mainly Diethylhexyl adipate (DEHA) and Di-isononyladipat (DINA)), citrates (esters of citric acids: mainly O-acetyl tributyl citrate (ATBC)), (organo)phosphates and trimellitate. Other plasticizers are groups of substances such as e.g. epoxidised soybean oil. As for cable sheathing, Di(2-ethylhexyl)phosphat, Tri(2-ehtylhexyl) phosphat and Tri-2-ehtyl-trimellitate are already used as plasticiser in a lager quantity (COWI, 2001; TNO, 2001).

These non-phthalate plasticizers have only partly been tested on their (eco-)toxicological properties as well as on their technical suitability. The test data for ten alternative plasticizers and two polymeric materials compiled by COWI (2001) are summarised in Table 10 and Table 11. A comparative assessment of the substances was considered difficult as only few and often different parameters were available for some of the substances. Quantitative ranking was not a possibility with the available data set. It can be summarised that some of the alternative plasticizers do show advantages from an environmental point of view compared to phthalates. Further tests, however, are considered necessary (UBA, 2007).

Due to the fact that these non-phthalate plasticizers are not chemically bound to the plastic, but dispersed in the matrix, they may also be released out of the material into the environment over time. Therefore, the German Federal Environmental Agency (Umweltbundesamt) recommends the use of plastics that show elastic properties without addition of plasticizers namely polyethylene or polypropylene. Also polyurethane can be used as PVC substituting material in some – mostly non EEE – applications (COWI, 2001). For most of the flexible-PVC products there are already alternatives free of plasticizers available.

The main application of phthalates in EEE is their use in PVC cables. For cables, there are PVC-free materials from PE (Polyethylene) or EVA (Ethyl-Vinylacetate-Copolymere) available that are technically suited for different voltages but more expensive then PVC cables (UBA, 1999).

Alternative plasticizers

The inherent properties for the investigated substances are summarised using key parameters: acute and local effects, carcinogenicity (C), genetic toxicity (M), reproductive toxicity (R), sensitisation, persistence, bioaccumulation and aquatic toxicity. If data are not available for all parameters or only from non standard test results a tentative assessment is given (shown in parentheses). For the materials an evaluation is given based on general polymer properties. The symbols: ● identified potential hazard, ○ no identified potential hazard, and – no data available.

Table 10 Inherent properties of alternative plasticizers (data compiled by COWI, 2001)

Name of substance	**CAS No.**	**Humans**			**Environment**		
		Acute & local effect (A/L)	**CMR**[d]	**Sensitisation**	**Persistence Bioaccu mulation**		**Aquatic Toxicity**
Diethylhexyl adipate	103-23-1	○/○	(○)[a]	○	○	○	● very toxic
O-acetyl tributyl citrate	77-90-7	○/○	○ M, R	○	● (inherent)	(●)	● (harmful)
Di(2-ethylhexyl) phosphate	298-07-7	●/●	○	○	● (conflicting)	○	● harmful
Tri(2-ethylhexyl) phosphate	78-42-2	(○)/●	○ M, C	-	●	○	● harmful
Tri-2-ethylhexyl trimellitate	3319-31-1	●/○	○	○	●	(●)	-
O-toluene sulfonamide	88-19-7	-/-	(○)[c]	-	(●)	○	-
2,2,4-trimethyl 1,3-pentandiol diisobutyrate	6846-50-0	-/-	-	-	-	-	-
Epoxidised soybean oil	8013-07-8	-/○	○	○	○	-	● toxic
Dipropylene glycol dibenzoate	27138-31-4	-/-	-	-	-[b]	(●)[b]	-[b]
Dioctyl sebacate	122-62-3	●/(○)	○	○	-	(●)	-
Polyadipates	-	-/-	-	-	- (persistent)	- (unlikely)	- (unlikely)
PU (MDI)	101-68-8	●/●	(○)	●	- (persistent)	- (unlikely)	- (unlikely)
LDPE	9002-88-4	-/-	-	-	- (persistent)	- (unlikely)	- (unlikely)

a: Foetotoxicity (reduced ossification) has been identified as the most sensitive effect in a developmental toxicity study.

b: QSAR estimates by Danish EPA leads to the classification N; R50/53 (May cause long term effects in the aquatic environment).

c: A test on reproductive effects performed on a product containing OTSA as impurity attributes effect to OTSA. No substance specific data available.

d: C,M,R indicated that the effect is investigated but no effects are seen.

The evaluated risks to humans or the environment are summarised for the investigated substances (polymer materials not included). The estimated exposure of humans is compared to the Acceptable Daily Intake (ADI). Predicted environmental concentrations in the aquatic environment (PEC) are compared to predicted no-effect concentrations (PNEC).

“Worst case” scenarios are used. The reader is referred to the main text and the data sheets for further explanations to the table. Parentheses show an assigned ADI. The symbols: ● ratio >1 (identified potential risk), ○ ratio <1 (no identified potential risk), and – no data available.

Table 11 Environmental and human health risks of alternative plasticizers (data compiled by COWI, 2001)

		Ratio of dose to ADI		Ratio of PEC to PNEC		
Substance	CAS no.	Consumer from products	Humans via environment	Water	Sediment	Remarks (ADI in mg/kgbw/d)
Diethylhexyl adipate	103-23-1	○	○	○	●	ADI 0.3
O-acetyl tributyl citrate	77-90-7	(○)[a]	(○)	○[b]	○[b]	Preliminary ADI 1.0[c]
Di(2-ethylhexyl) phosphate	298-07-7	○	○	○	○	Group ADI 0.05
Tri(2-ethylhexyl) phosphate	78-42-2	○	○	○	○	Group ADI 0.05
Tri-2-ethylhexyl trimellitate	3319-31-1	(○)	○	○[d]	○[d]	Assigned
O-toluene sulfonic acid amide	88-19-7	(○)	(○)	-	-	Assigned
2,2,4-trimethyl 1,3-pentandiol diisobutyrate	6846-50-0	-	-	-	-	No effect and exposure data
Epoxidised soybean oil	8013-07-8	-	-	-	-	No exposure data
Dipropylene glycol dibenzoate	27138-31-4	(○)	(○)	-	-	Assigned ADI 0.05
Dioctyl sebacate	122-62-3	○	●	-	-	Group ADI 0.05

a: Dose reaches 37% of preliminary ADI in teething ring scenario.

b: Tentative estimate based on only one ecotoxicity study.

c: Preliminary ADI from Nikiforov (1999)

d: Data set comprise only two acute values and one chronic NOEC value.

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5.1.4 MCCP

There are only limited information public available on substitutes for MCCP. Nevertheless these substitutes themselves show structural similarities to hazardous substances.

Where MCCP is only used as a softener, DINP is mentioned in the POSH program as an alternative. As pointed out in chapter 3.7, DINP have structural similarities to phthalates which have hazardous properties.

For paint and rubber/polymers (except PVC), MCCP has been used as softeners. As a substitute long-chained chlorinated paraffins (LCCP) are taken as an alternative. Short- and medium-chained chlorinated paraffins are classified as hazardous substances. Long-chained chlorinated paraffins are structurally related compounds.

For both application areas further research is required to identify suitable substitutes.

5.1.5 SCCP

Similar to the situation for medium-chained chlorinated paraffins, also for short-chained chlorinated paraffins only limited information on substitutes are public available. In another application area, as metal working fluids, the use of short-chained chlorinated paraffins has been restricted already since a long time. As substitutes in some cases medium-chained chlorinated paraffins have been used, which are problematic too.

Further research is needed to identify suitable substitutes for short-chained chlorinated paraffins.

5.1.6 Nonylphenol[43] and nonylphenol ethoxylates

Nonylphenol ethoxylates have already been replaced in many application areas (see UBA, 2003). Therefore it is reasonable to assume that for the remaining small-volume applications

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[43] 4-nonylphenol (branched) and nonylphenol

for EEE substitutes are available. Here additional information is required from the manufacturing regarding the actual situation (this will be a discussion point for the expert meeting on 06 May 2008).

5.1.7 Halogenated organic compounds

For a number of substances belonging to this group analysis of substitutes have been made within this study (see section 5.1.1 and section 5.1.2). Within this study, however, it has not been possible to analyse the availability of substitutes for all halogenated organic compounds. Several manufacturers of EEE intend to phaseout brominated flame retardants (BFR) and PVC in all their applications proving that substitution of organohalogen compounds in EEE is possible at least for the majority of applications (Greenpeace 2008).

5.2 Impacts of substitution

Impacts of substitution may arise from administrative burden (i.e. information and verification activities), from technical costs of phase-out, of additional hazardous substances, or other monetary losses of compliance. On the other side, experiences with the implementation of the existing RoHS Directive have shown that there are economic benefits, too.

In the previous section, existing information about substitutes were presented. However, the level of detail is not specific enough to quantify the impacts metioned above. Therefore, the contractor intends to gather more details through structured collection of expert knowledge at the upcomming workshop on 06 May 2008.

6 Policy options

6.1 RoHS versus REACH

In June 2007 the REACH regulation entered into force. REACH defines the European legal framework for the registration, evaluation, authorisation and restriction of chemicals. REACH has no direct influence on the RoHS Directive, but it is strongly related to the definition of hazardous substances which themselves are a key element of RoHS.

REACH refers to substances in general, not to specific industrial sectors. It covers the whole life cycle of a substance, including its direct use, its use in preparations and its presence in articles. By contrast, RoHS focuses on substances used in electrical and electronic applications. RoHS aims to achieve a reduction of the content of hazardous substances in these products taking their recycling and general waste treatment into account. In a recent study an overview on relations and potential impacts between RoHS and REACH is given

(ARCADIS ECOLAS and RPA 2007). In the following we will concentrate on elements of REACH which are of importance for the identification and for the prioritisation of hazardous substances which might be included into RoHS.

REACH replaces several regulations related to chemicals while the RoHS Directive coexists in parallel to REACH. Similar to other regulations referring to substances, the future development of the RoHS Directive should use new information on substances which will be generated due to the implementation of REACH (especially regarding hazardous properties of substances and regarding the use of the substances).

For example, new data on substances will become available during the registration phase. For phase-in-substances transitional provisions for the registration are applicable (Article 23 REACH). For high production volume chemicals and very hazardous substances, registration has to be completed until 1 December 2010, for medium production volume chemicals on 1 June 2013 and for low production volume substances by 1 June 2018. Therefore, for the ongoing revision of the RoHS directive new data on substances related to REACH are not yet available.

Nevertheless, REACH has an important impact on the on-going revision of the RoHS Directive by defining “substances of very high concern” (SVHC). Such a definition did not exist before. Substances of very high concern cause a high risk to humans and the environment and should be replaced by suitable alternative substances or technologies as soon as possible (REACH Article Authorisation). Substances which may become substances of very high concern are defined in Article 57 and the corresponding Annex XIII of REACH (Annex XIII Criteria) (substances which are subject of authorisation are listed in Annex XIV).

Under waste legislation, hazardous substances are those that are considered to be dangerous under Directive 67/548/EEC. Therefore RoHS refers to the definition of dangerous substances as given in Dir 67/548/EEC. Substances of very high concern as defined by REACH are only a part of the large group of dangerous substances as defined by Dir 67/548/EEC. Therefore, even in the future, 'hazardous' under RoHs will be wider in scope than SVHC under REACH.

REACH does not limit the possibility of setting restrictions (more similar to the RoHS approach) to substances of very high concern, but authorisation under REACH is only for substances of very high concern.

In the present report hazardous substances have been identified which are present in electrical and electronic equipment. It has been assessed whether these substances are substances of very high concern as defined by REACH.

Several titles in REACH refer to substances of very high concern defined in article 57 of REACH. Some of them are only of minor or of no importance for the identification of hazardous substances which might be included in RoHS:

- Article 7.2 REACH defines the obligations to inform about specific substances of very high concern in articles. This provision does not cover all substances of very high concern, but only those which have been selected as candidate substances for a potential inclusion in Annex XIV. In addition, Article 7.2 sets concentration limits for information requirements. Both elements (candidate substances and concentration limits) are necessary to set priorities for the actions which are connected with authorisation and with communication within the supply chain under REACH. The RoHS Directive has a much narrower scope (not covering nearly[44] all substances with a production volume of 1 ton/year and more in nearly[45] all uses, but regulating a limited number of hazardous substances in electrical and electronic equipment).
- Article 59 REACH describes a specific selection process. This process aims to identify substances of very high concern (as defined by article 57 REACH) which are considered as candidates for being subject of authorisation ("substances of the candidate list"). A specific Annex XV dossier is required in order to argue for an inclusion of a substance in the candidate list. Such dossiers will be prepared by the Member State authorities or the European Chemicals Agency on request by the Commission. There is no deadline for the candidate list, but there is a deadline for the Agency to propose a list of priority substances for inclusion in Annex XIV by 1 June 2009. The candidate list has to be published before.
- Candidate substances have to meet the criteria described in REACH Article 57 (which determine substances of very high concern). Beyond this, there are no further criteria given for the selection of the candidate substances from the large group of substances of very high concern. (The criteria given in Article 58 refer to the selection of substances from the candidate list to Annex XIV, see next bullet point).
- For the next step in the authorisation procedure, for the selection of substances which are included in Annex XIV criteria for priority setting are given in article 58.3 Priority shall normally be given to substances with PBT or vPvB properties / or wide dispersive use / or high volumes. This recommendation does not reflect the scope of the RoHS Directive which is specifically regulating hazardous substances in electrical and electronic equipment.
- Similarly to the situation described above for the candidate list, also the identity and the number of substances which will be included in Annex XIV in practice will be influenced by the working capacity of the authorities involved.

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[44] Certain groups of substances are excluded from REACH or from certain titles of REACH (see REACH Article2)

[45] Certain uses of substances are excluded from REACH, especially if they are already covered by existing European regulations (e.g. active substances in pesticides and biocides).

- In the process of selecting a substance for inclusion in Annex XIV as well as in the process of granting of authorisation it will be an important aspect whether the substance under consideration is already regulated by other regulations. These sector-specific regulations (such as the RoHS Directive) are seen as important pieces of legislation for managing hazardous substances, which will not be (or as far as they are not) duplicated by REACH. If a substance is already restricted or banned under the RoHS Directive, such use will not be covered by the REACH authorisation obligations, leaving the RoHS ban intact.

During the stakeholder consultations several times the recommendation was given that new substance restrictions should be regulated under REACH. This has been done on the basis of the assumption that all substances of very high concern will be included in the candidate list and are expected to be included in Annex XIV. As described above, at present it is not known which and how many substances will become candidate substances neither which substances will be listed in Annex XIV and will be subject to authorisation. There is no automatism which would ensure consideration of all substances of very high concern under the authorisation procedure of REACH, at least not in the short or medium term.

Sector-specific regulations supplementing REACH are important. REACH will not be able to ensure the sustainable handling of chemicals in all sectors neither has it been foreseen to act in such a way as a stand-alone-regulation.

From the various elements which are used in REACH for priority setting, this study especially used the definitions of REACH for substances of very high concern. The further selection process in this study refers to the scope of the RoHS Directive as described in chapter 1, which in general refers to dangerous substances as defined under Directive 67/548/EEC.

6.2 Overview on possible policy options

DG Environment has proposed possible policy options for the inclusion of new hazardous substances in the scope of RoHS. An overview on the outlined policy options including the pros and cons of each option is given in Table 12.

An online consultation was launched by the Commission to ask stakeholders for their opinion on the outlined options and to invite the stakeholders to propose additional options. The electronically submitted information is available at:
http://circa.europa.eu/Public/irc/env/rohs_2008_review/home.

The great majority of industry stakeholders do not see the need for extending the ban to other substances in EEE; many of them point to the chemicals legislation (REACH) for dealing with potential environmental and health risks from hazardous substances in EEE, while some do acknowledge that RoHS could be used as the legal instrument, if risk and economic assessments would justify such move. All Member States which participated in the consultation are against relegating the issue to REACH and some point to the inadequacy of REACH for problematic substances in EEE (too high quantitative thresholds, too long deadlines, differentiated treatment for imported articles). NGOs support clearly the inclusion of new hazardous substances into the scope of RoHS and propose a number of substances to be included with priority, as well as extensive reference material. Alternative ways of managing risks (waste management of EEE, easy removability of parts containing hazardous substances) outlined in the consultation case are mostly considered as part of the solution; labelling is almost unanimously rejected, since it is deemed likely to bring confusion. The "classical" option of introducing a general ban for new substances with exemptions seems to be preferred by the stakeholders in favour of expanding RoHS and could apparently be tolerated by parts of industry, provided, of course, that sufficient supporting evidence is available (EU Commission 2008).

Table 12 Overview on possible policy options appropriate to new hazardous substances

Policy option	Pros / advantages	Cons / disadvantages
(1) Not add any new justified substances under RoHS and deal with them under REACH	Simpler and faster procedure for adopting the revised RoHS; reduced risk for confusion (the "RoHS substances" should be widely known by now by interested stakeholders, any remaining hazardous substance will be tackled by REACH). REACH provides mechanisms to assess the risk due to dangerous substances including those used in EEE. In case of risk evidence at use or waste level, REACH authorisation or restriction will then apply to manage the risks on an appropriate way;	If evidence points to a different direction, doing nothing could be interpreted as disregarding the legislator's mandate (Article 6 of RoHS); missing the opportunity for minimising risks for health and the environment much earlier than it would have been possible with REACH. Authorisation under REACH will only apply to European producers of EEE.
(2) Add new substances but only for certain categories of EEE in the scope of RoHS	Extension, albeit limited (by the reduction of product categories covered), of the environmental and health benefit of the Directive; avoiding the administrative burden associated with managing exemption requests and monitoring implementation of exemptions;	Leaving unexploited potential for further increasing the environmental benefit of the Directive; some sectors may feel disadvantaged, especially if there is competition in use between included/excluded products; possible need for a review clause (like is the case now with cat.8&9 products), creating room for uncertainty and speculation.
(3) Add new substances for all EEE, in the scope of RoHS but with exempted applications	Extension, albeit limited (by the exemptions), of the environmental and health benefit of the Directive; smooth transition into the "extended" ban; continuation of a transparent approach already known to manufacturers and other	Complaints about length and complexity of exemptions' process have been submitted; possible uncertainty as to approval and the time horizon for validity of the exemptions; it must be checked what the exemptions represent in terms of % of the overall quantity of the

Policy option	Pros / advantages	Cons / disadvantages
	stakeholders;	hazardous substances used in EEE; the time horizon should be compared with REACH, probably on a case by case basis.
(4) Add new substances for all EEE without exemptions at a deferred date	Extending as much as possible the environmental benefit of the Directive and giving a clear signal to manufacturers; avoidance of confusion; faster and simpler procedure for adopting the revised RoHS;	Postponement could be as long as the time needed for the hazardous substance substitution in the most critical applications; the time horizon should be compared with REACH, probably on a case by case basis.
(5) Add new justified substances under RoHs only if substitutes already available and fully investigated	Easier adoption process; transition into the "extended" ban in the smoothest possible way for manufacturers and with certainty that substitution will not incur excessive costs to society or have overall adverse environmental consequences. Any new substance ban must be based on sound scientific evidence with due consideration of the availability and adequacy of substitutes. Any decision leading to the inclusion of a new substance in RoHs should be based on an evaluation and risk assessment process. A reasonable time period to phase out existing uses of a targeted substance is required.	List of substances added may be too short, hence reduced environmental benefit; inclusion of a new hazardous substance in RoHS, even with exemptions and postponements, spurs efforts and research into the availability and characteristics of possible substitutes, which would otherwise not take place; a requirement for full investigation of substitutes might prolong the process if the necessary data are not already available to a large extent.
(6) Link inclusion of substances at a given deadline (e.g 2014) with the results of a report on the efficiency of waste (WEEE) management for removing hazardous substances from the waste stream	A purely risk based approach, hoping that all stakeholders will behave responsibly and the benefits of the WEEE Directive will be reaped in their entirety; manufacturers retain full flexibility in their product design, while being aware that certain hazardous substances have been identified as possible candidates for RoHS;	It is not possible to foresee or identify the pathways of dissemination of a HS in the waste stream if separate collection and state of the art treatment of WEEE do not take place sufficiently. Experience has shown that it is very hard to collect comprehensive and reliable data (see latest UNU report for WEEE review), which would be necessary if the risk for particularly harmful hazardous substances were to be properly managed. Such an option is not expected to deliver the necessary environmental benefit, if not combined with other actions; could be appropriate as one among other indicators/milestones in a review process (see also option (7).
(7) Not add any new substances but introduce labelling requirements (for example certain phthalates for certain Medical Devices)	Faster and easier adoption process, since such a "light" requirement would necessitate less investigation and would be most probably more readily accepted. Lower cost and easier transition (increased design flexibility) for manufacturers; could be examined in connexion with the	Lower environmental benefit, since the hazardous substance would still be present in the waste; possible confusion between the hazardous substances "for labelling" and hazardous substances "for restriction".

Policy option	Pros / advantages	Cons / disadvantages
	risk that the specific use of the given HS presents;	
(8) Not add any new substances but introduce obligation for easy removability of parts containing hazardous substances	Faster and easier adoption process; could be even adopted as a "horizontal" implementing measure under the EuP Directive; a link could be created with the treatment requirements (Annex II) of the WEEE Directive; low cost for manufacturers, could become part of their more general eco-design strategy;	A solid and complete WEEE separate collection/recycling/treatment of hazardous waste chain should be in place, which is far from being the case now in the 27 MS (or, for that matter, in developing countries where, unfortunately, large quantities of WEEE end up). It is very doubtful whether such an option alone would suffice for ensuring a high level of environmental protection.

6.3 Proposed policy options for candidate substances

The set of possible policy options outlined by the EU Commission (see Table 12) was used as basis for the establishment of policy options for the single candidate substances discussed in chapter 4. The proposed policy options for each candidate substance are presented in Table 13.

As discussed in section 4.1.7, it is proposed that not only the brominated and chlorinated substances TBBP-A, HBCDD as well as medium and short-chained chlorinated paraffins should be restricted by RoHS, but all organohalogen compounds including brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins and halogenated polymers. They should be phased out from electrical and electronic equipment in order to fulfil the precautionary principle. Therefore also policy options are proposed for these compounds.

Table 13 Proposed policy options for candidate substances

Candidate substance	Proposed policy option	Remarks
TBBP-A	Policy option 3: Add TBBP-A for all EEE in the scope of RoHS; exempted from this restriction is the use of TBBP-A as reactive flame retardant in epoxy and polycarbonates resins	Through this policy option the use of TBBP-A as additive flame retardant shall be restricted.
HBCDD	Policy option 4: Add HBCDD for all EEE without exemptions within 18 months after inclusion of the candidate substance in RoHS	The use of HBCDD as additive flame retardant in HIPS shall be restricted.
DEHP	Policy option 3: Add DEHP for all EEE in the scope of RoHS with (possible) exempted applications	Through this policy option the use of DEHP as plasticiser shall be restricted; applications other than the use as plasticisers may be exempted if applicants can prove that the elimination or substitution is technically or scientifically impracticable, or that the negative

Candidate substance	Proposed policy option	Remarks
		environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits thereof.
BBP	Policy option 3: Add BBP for all EEE in the scope of RoHS with (possible) exempted applications	Through this policy option the use of BBP as plasticiser shall be restricted; applications other than the use as plasticisers may be exempted if applicants can prove that the elimination or substitution is technically or scientifically impracticable, or that the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits thereof.
DBP	Policy option 3: Add DBP for all EEE in the scope of RoHS with (possible) exempted applications	Through this policy option the use of DBP as plasticiser shall be restricted; applications other than the use as plasticisers may be exempted if applicants can prove that the elimination or substitution is technically or scientifically impracticable, or that the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits thereof.
MCCP	Policy option 4: Add MCCP for all EEE without exemptions within 18 months after inclusion of the candidate substance in RoHS	Need for clarification whether or not MCCPs are still used in EEE and can be found in the final product. If, however, it is confirmed that MCCPs are still used in EEE, policy option 4 is proposed.
SCCP	Policy option 4: Add SCCP for all EEE without exemptions within 18 months after inclusion of the candidate substance in RoHS	Need for clarification whether or not SCCPs are still used in EEE and can be found in the final product. If, however, it is confirmed that SCCPs are still used in EEE, policy option 4 is proposed.
Nonylphenol/ Nonylphenolethoxylate	Policy option 4: Add nonylphenol/ nonylphenolethoxylates for all EEE without exemptions within 18 months after inclusion of the candidate substance in RoHS	Need for clarification whether or not nonylphenol/ nonylphenolethoxylates are still used in EEE and can be found in the final product. If, however, it is confirmed that nonylphenol/ nonylphenolethoxylates are still used in EEE, policy option 4 is proposed.
Halogenated organic compounds	Policy option 3: Add organohalogen compounds for all	Applications may be exempted if applicants can prove that the

Candidate substance	Proposed policy option	Remarks
	EEE in the scope of RoHS with (possible) exempted applications	elimination or substitution is technically or scientifically impracticable, or that the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits thereof.

6.4 Further proposed policy options

For beryllium and beryllium oxide the following policy options are proposed which support the safe recycling of beryllium-containing EEE:

- Beryllium and beryllium oxide containing EEE should be labelled; exempted from this labelling requirement are beryllium-containing alloys with up to 2 weight percent beryllium;
- Beryllium- and beryllium-oxide-containing parts (exceeding 2 weight percent beryllium) should be easily removable during dismantling of the EEE.

7 Open points

During the stakeholder consultation on hazardous substances not regulated by RoHS contradictory information have been provided with regard to uses of diarsenic trioxide, dinickel trioxide and Dimethylformamide (DMF) in EEE (Table 14). According to most manufacturers these three hazardous substances are not used anymore in EEE. Both arsenic and nickel compounds have already been restricted by Annex XVII to REACH (item 19 and item 27, respectively). Few stakeholders stated, however, that these substances are still used in EEE applications. Further discussions with the respective stakeholders are necessary in order to clarify whether or not these substances are still used in EEE.

Table 14 Hazardous substances with further need for clarification

Substance name	CAS No.	Main use in EEE	Quantity	Classification
diarsenic trioxide; arsenic trioxide[46]	1327-53-3	Fining agent in certain special glasses and glass ceramics, however not clear whether still used for this application; Copper foil in printed circuit boards	<1%	Carc. Cat. 1; R45 T+; R28 C; 34 N; R50-53
dinickel trioxide[47]	1314-06-3	Used as colouring agent in certain special glasses. In certain optical / filter glasses + in radiation shielding applications (e.g. welding); Part of ceramics (varistors, NTC)	<1% up to 10 % typically 20 % in NTC, 1% in varistors	Carc. Cat. 1; R49 R43 R53
Dimethylformamide (DMF)	68-12-2	High voltage/capacity aluminium foil electrolytic capacitors; power supplies; Printed wiring board epoxy: epoxy hardener material	Minor use in EEE	Repr. Cat. 2; R61 Xn; R20/21 Xi; R36

With regard to the substitution of the candidate substances, various data are available on halogenfree flame retardands and non-phthalate plasticizers (section 5.1.1, section 5.1.2 and section 5.1.3). However, for most of the possible substitutes published information on (eco-) toxicological endpoints is only scarcely available.

For the other candidate MCCP, SCCP and nonylphenolethoxylate only limited information on substitutes is publicly available at all.

Further research is required to identify not only suitable substitutes, but to determine also their (eco-) toxicological endpoints in order to be able to conclude with certainty if the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits.

During the stakeholder consulation only limited information was received by manufacturers on the questions which hazardous substances are present in the electrical and electronic components and in which quantities these substances are contained in EEE. According to statements by equipment manufacturers they don’t get detailed information on the composition of EEE by their component suppliers.

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[46] Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH)

[47] Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH) for those applications where nickel is likely to result in direct and prolonged skin exposure

In contrast to the automotive industry which has developed the Global automotive Declarable Substance List (GADSL), the electronic industry does not yet have a standardised material declaration system. The International Electrotechnical Commission (IEC, Technical Committee 111) is currently working on an international standard for the declaration of materials for the electrical and electronics industries. The final standard is scheduled by October 2010. Available other declaration systems (e.g. the so-called Umbrella specifications (section 2.2.2) developed by the German Electrical and Electronic Manufacturer's Association (ZVEI) are, according to industry information, not internationally accepted.

The suppliers do often only confirm a general "RoHS Compliance" meaning that the supplied components do comply with Directive 2002/95/EC (RoHS Directive). Detailed information on the exact content of other hazardous substances in EEE is often not provided by the suppliers. In some best cases, suppliers do declare the content of the current RoHS restricted substances (Cd, Pb, Hg, Cr (VI), PBB and PBDE) in addition to JIG Level A / B substances and some recyclable metals (e.g. Cu, Au, Mg, Ni, Pd and Ag).

As mentioned in Section 2.2.4, the existing Joint Industry Guide is currently being reviewed and a new version is going to be elaborated that will, according to industry information, only contain one list of declarable substances without distinction of Level A and B substances. This list will comprise substances that are regarded as substances of very high concern (SVHC) according to REACH and that are relevant for electrical & electronic equipment. The Draft JIG Phase 2 Document is scheduled for 2008.

Due to this existing lack of information within the supply chain of the electronic industry, the set-up of a comprehensive inventory of hazardous substances in specified electrical and electronic components turned out to be difficult. Even more difficult was the quantitative estimation of hazardous substances in electrical and electronic components because very little information on concentrations of hazardous substances in EEE was received by the manufacturers.

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9 Annexes

9.1 Criteria for the identification of persistent, bioaccumulative and toxic substances, and very persistent and very bioaccumulative substances

A substance is identified as a PBT substance if it fulfils the criteria in Sections 1.1, 1.2, and 1.3 below.

A substance is identified as a vPvB substance if it fulfils the criteria in Sections 2.1 and 2.2 below. This annex shall not apply to inorganic substances, but shall apply to organo-metals.

1. PBT-substances

A substance that fulfils all three of the criteria of the sections below is a PBT substance.

1.1. Persistence

A substance fulfils the persistence criterion (P-) when:

- the half-life in marine water is higher than 60 days, or
- the half-life in fresh- or estuarine water is higher than 40 days, or
- the half-life in marine sediment is higher than 180 days, or
- the half-life in fresh- or estuarine water sediment is higher than 120 days, or
- the half-life in soil is higher than 120 days.

The assessment of the persistency in the environment shall be based on available half-life data collected under the adequate conditions, which shall be described by the registrant.

1.2. Bioaccumulation

A substance fulfils the bioaccumulation criterion (B-) when:

- the bioconcentration factor (BCF) is higher than 2 000.

The assessment of bioaccumulation shall be based on measured data on bioconcentration in aquatic species. Data from freshwater as well as marine water species can be used.

1.3. Toxicity

A substance fulfils the toxicity criterion (T-) when:

- the long-term no-observed effect concentration (NOEC) for marine or freshwater organisms is less than 0,01mg/l, or
- the substance is classified as carcinogenic (category 1 or 2), mutagenic (category 1 or 2), or toxic for reproduction (category 1, 2, or 3), or

- there is other evidence of chronic toxicity, as identified by the classifications: T, R48, or Xn, R48 according to Directive 67/548/EEC.

2. vPvB – substances

A substance that fulfils the criteria of the sections below is a vPvB substance.

2.1. Persistence

A substance fulfils the very persistence criterion (vP-) when:

- the half-life in marine, fresh- or estuarine water is higher than 60 days, or
- the half-life in marine, fresh- or estuarine water sediment is higher than 180 days, or
- the half-life in soil is higher than 180.

2.2. Bioaccumulation

A substance fulfils the very bioaccumulative criterion (vB-) when:

- the bioconcentration factor is greater than 5 000.

9.2 Component structure of electrical and electronic equipment

Family #	Family	Group	Subgroup #	Subgroup / typical components
1	Wire, Cable, Connectors, Cable Assemblies, IC Sockets	Wire	1.1	to be defined and differentiated
		Cable	1.2	to be defined and differentiated
		Connectors	1.3	Connector Metal Housing
			1.4	Connector Plastic Housing
		Connectors / Cable Assemblies	1.5	to be defined and differentiated
2	Switches, Relays, Electromechanical Components	Switches	2.1	to be defined and differentiated
		Relays	2.2	to be defined and differentiated
		Electromechanical Components	2.3	to be defined and differentiated
		Fuses and arresters	2.4	Surge voltage arrester
3	Semiconductors, ICs, Transistors, Diodes		3.1	Plastic axial diode
			3.2	Surface mount diode in melf packages
			3.3	Power schottky and rectifier diode
			3.4	Trisil, transil and schottky diodes in plastic packages
			3.5	Thyristors
			3.6	Small signal transistors in metal can packages
			3.7	Power products in TO3 packages
			3.8	Small signal transistors in TO92 package
			3.9	Small outline transistors and diodes – low power
			3.10	Small outline transistors and diodes – high power
			3.11	Surface mount devices medium power transistors
			3.12	Through hole package medium power transistors
			3.13	Medium/high power transistor/thyristor isolated packages
			3.14	GBU package
			3.15	R.F. hermetic packages with stud
			3.16	R.F. ceramic packages with stud

Family #	Family	Group	Subgroup #	Subgroup / typical components
			3.17	R.F. hermetic flanged packages
			3.18	R.F. studless ceramic packages
			3.19	R.F. ceramic flanged packages
			3.20	Ceramic dual in line package
			3.21	Frit-seal ceramic package with bulls-eye (lens)
			3.22	Side brazed ceramic dual in line package with and without lens
			3.23	J leaded chip carrier
			3.24	Ceramic leaded chip carrier
			3.25	Ceramic quad flat packages
			3.26	Ceramic pin grid array
			3.27	Dual in line plastic packages – frame 0.25
			3.28	Power dual in line plastic packages – frame 0.40
			3.29	Shrink dual in line plastic packages
			3.30	P-dip zeropower/timekeeper
			3.31	Small outline plastic packages
			3.32	Shrink small outline plastic packages
			3.33	Power SO packages
			3.34	TO220 packages
			3.35	Multiwatt
			3.36	Pentawatt, heptawatt
			3.37	Flexiwatt packages
			3.38	Clipwatt packages
			3.39	Single in line plastic packages
			3.40	Plastic leaded chip carrier
			3.41	Thin quad flat packages
			3.42	Low quad flat packages
			3.43	Plastic quad flat packages
			3.44	High quad packages

Family #	Family	Group	Subgroup #	Subgroup / typical components
			3.45	Thin small outline packages – frame Cu
			3.46	Thin small outline packages – frame Alloy42
			3.47	Thin small small outline packages
			3.48	Low profile ball grid array packages
			3.49	Thin fine pitch ball grid array packages
			3.50	Low profile fine pitch ball grid array packages
			3.51	Plastic ball grid array packages
			3.52	Very-thin-profile fine pitch ball grid array packages
			3.53	Very thin fine pitch quad flat package no lead
			3.54	Flip chip CSP
			3.55	Micromodule (potting or molding process)
			3.56	Micromodule with metal ring
4	Capacitors	Electrolytic Capacitors	4.1	Speciality Polymer Aluminium Electrolytic Capacitor (SMD)
			4.2	Aluminium Electrolytic Capacitor (axial)
			4.3	Aluminium Electrolytic Capacitor (radial)
			4.4	Aluminium Electrolytic Capacitor (Screw)
			4.5	Aluminium Electrolytic Capacitor (SMD)
			4.6	Aluminium Electrolytic Capacitor (Snap In)
			4.7	Aluminium Electrolytic Capacitor (Snap In - TS type)
		Ceramic Capacitors	4.8	Ceramic Capacitor MLCC
		Metallized Film Capacitors	4.9	Metallized Film Capacitor (Boxed)
			4.10	Metallized Film Capacitor (uncoated)
			4.11	Metallized Film Capacitor (Film Chip Capacitor)
		Tantalum Capacitors	4.12	Tantalum Capacitor (SMD)
5	Resistors, Potentiometers, Thermistor NTC	Leaded Resistors	5.1	Cemented wirewound
			5.2	Cemented wirewound precision
			5.3	Low ohmic surge
			5.4	Low ohmic

Family #	Family	Group	Subgroup #	Subgroup / typical components
			5.5	High ohmic / high voltage
			5.6	Professional / Precision
			5.7	Fusible
			5.8	Professional power metal film
			5.9	Radial mounted power film
			5.10	Radial mounted power wirewound
			5.11	Standard metal film
			5.12	Stand-up miniature power film
			5.13	Stand-up miniature wirewound
			5.14	Ultra precision
		SMD Resistors	5.15	SMD Array
			5.16	SMD Flat chip
			5.17	SMD Thick film flat array
			5.18	Thick film flat chip
			5.19	MELF
			5.20	SMD Power thick film flat chip
		Potentiometers	5.21	to be defined / differentiated
		Thermistor NTC	5.22	Thermistor NTC (disk)
			5.23	Thermistor NTC (SMD)
6	Inductors, Coils, Filters, Transformers, Power Supplies	to be defined and differentiated	6.1	ZVEI: Group A to T; assignment to functional groups not possible
7	Active Radio Frequency Products and Antennas	to be defined and differentiated	7.1	
8	Crystals, Oscillators	to be defined and differentiated	8.1	
9	Optoelectronics, LEDs, LCDs, Lasers, Displays	to be defined and differentiated, part of family 3	9.1	
10	Audioelectronics, Speakers, Microphones	to be defined and differentiated	10.1	

Family #	Family	Group	Subgroup #	Subgroup / typical components
11	Electric motors, fans	to be defined and differentiated	11.1	
12	Printed Circuit Boards, Multilayer, Flexlayer	ZVEI: functional model available	12.1	
13	Solder	to be defined and differentiated, part of family 3	13.1	

9.3 Composition of subgroups / typical components:

Please specify number and name of subgroup according to table Component Structure of Electrical and Electronic Equipment here:

Subgroup # : "please specify"
Subgroup / Typical component: "please specify"

Hazardous Substance[48] / Details	"Substance A"	"Substance B"	"Substance C"	"Substance D"	"Substance E"	"Substance F"
CAS No.						
Classification (according to 67/548/EEC)						
Concentration range of HS in subgroup/typical component [% or ppm]						
Quantity of subgroup/typical component produced/used per year [kg]						
Function of HS in component						
Remark						

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[48] Name of hazardous substance (HS) contained in the subgroup/typical component; the following substances are considered as hazardous substances:
- substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC,
- substances which are persistent, bioaccumulative and toxic (PBT) or which are very persistent and very bioaccumulative (vPvB);
- substances with evidence (Category I) or evidence of potential endocrine disruption (Category II).

9.4 Inventory of hazardous substances and materials in EEE

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
1	Tetrabromo bisphenol A	79-94-7	Reactive FR in PCB laminates. Additive FR in ABS	40,000 tpa Reactive: 1000ppm	N; R50/53[49]	N	Final (HH) Draft (Env)
2	Hexabromocyclododecane (HBCDD)	25637-99-4	Flame retardant in High Impact Polystyrene (HIPS) e.g. in audio-visual equipment, wire, cables	1-7%	Proposed classification: N R50-53; PBT	Y	Draft
3	Bis (2-ethylhexyl) phthalate (DEHP)[50]	117-81-7	Plasticizer in PVC cables; Dielectric fluid in capacitors; Encapsulation/potting of electronics components	<0.1%	Repr. Cat. 2; R60-61	Y	Draft
4	Butylbenzylphthalate (BBP)[51]	85-68-7	Plasticizer in PVC cables Encapsulation/potting of electronics components	<50%	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	Y	Draft
5	Dibutylphthalate (DBP)[52]	84-74-2	Plasticizer in PVC cables; Encapsulation/potting of electronics components	<5%	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	Y	Final + Comm Recomm.

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[49] TBBP-A is included in the OSPAR List of Chemicals for Priority Action (Update 2007)

[50] DEHP is a Water Framework Directive Priority Substance, and is also subject to a comprehensive risk assessment under EC 793/93. Risk management proposals are being prepared by the Swedish rapporteur; Restricted for toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC.

[51] Restricted for use in toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			Silber conductive paint for variable resistors	~1%			
6	Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	secondary plasticisers in PVC (cable) flame retardant plasticisers in rubbers Shipping Tube End Cap (AllegroMicro)		currently not classified according to 67/548; proposed classification: N; R50/53 ED Cat. 1		Final Env.
7	Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	flame retardant in rubber; mainly used as an additive in metal working fluids, in production process, but not present in final product[53]; in industrial and commercial sensors (coin sensors, paper sensors, etc.) where it is found on conncector wires of the sensor assembly		Carc. Cat. 3; R40 N; R50-53	Y	Final + Comm Recomm.
8	Nonylphenol/ Nonylphenol ethoxylates	9016-45-9	Surfactants that can be used in coatings for films in EEE ad in formulations to clan printed circuit boards; adhesives	adhesives < 2%	ED Cat. 1	Y	Final + Comm Recomm.

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[52] Restricted for use in toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

[53] Regulated by 76/769/EC and REACh Annex XVII (item 27) for metal working

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
9	Diarsenic trioxide; arsenic trioxide[54]	1327-53-3	Fining agent in certain special glasses and glass ceramics, however not clear whether still used for this application; Copper foil in printed circuit boards	<1%	Carc. Cat. 1; R45 T+; R28 C; 34 N; R50-53	Y	-
10	dinickel trioxide[55]	1314-06-3	Used as colouring agent in certain special glasses. In certain optical / filter glasses + in radiation shielding applications (e.g. welding); Part of ceramics (varistors, NTC)	<1% up to 10 % typically 20 % in NTC, 1% in varistors	Carc. Cat. 1; R49 R43 R53	Y	-
11	Dimethylformamide (DMF)	68-12-2	High voltage/capacity aluminium foil electrolytic capacitors; power supplies; Printed wiring board epoxy: epoxy hardener material	Minor use in EEE	Repr. Cat. 2; R61 Xn; R20/21 Xi; R36		-
12	Petrolatum	8009-03-8	Used in solder fluxes/pastes; Ceramics (found on the conductive paste used in electrical pattern printing process of the ceramic substrate); Gaskets of EPDM		Carc. Cat. 2; R45 Nota N: The classification as a carcinogen needs not apply if the full refining history is known and it can be	Y	-

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[54] Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH)

[55] Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH) for those applications where nickel is likely to result in direct and prolonged skin exposure

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
					demonstrated that the substance from which it was produced is not a carcinogen.[56]		
13	PVC	9002-86-2	Cable insulation, sleeve material of capacitors Printed Circuit Boards Sealing for aluminium electrolyte capacitors		Possible formation of dioxins and furans during incineration	N	-
14	Beryllium metal	7440-41-7	CuBe-alloys; NiBe-alloys CuBe alloys are used as conducting spring material in electronic connectors, IC sockets, switches, relays, micro motors Precision co-axial connectors to meet high reliability (xks connects) standard IEEE Std 287-2007 to 110 Ghz.	0.2-2 w%	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	Y	-

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[56] Petrolatum is a specific petroleum substance. For the purpose of their carcinogenicity classification in the Dangerous Substances Directive 67/548/EEC all petroleum substances were allocated to a number of distinct groups referring to their refinery processing history.
These groups include “Highly Refined Base Oils”, “Paraffin and Hydrocarbon Waxes” and “Petrolatum”. The first two groups are classified as non-carcnogenic, whereas the group “Petrolatum” is classified as carcinogenic, category, unless base oil from which it derives is not carcinogenic (Nota N in Annex I of the Directive, see table above). Petrolatum is used as a raw material for the cosmetic industry. For petrolatum which is used here it is demonstrated that it is not a carcinogen, according to the test method IP 346 (legal requirement for these materials for non-carcinogenicity) (COLIPA 2004: Joint COLIPA/EWF recommendation. Safety of petrolatum as a raw material for the cosmetic industry. The European Cosmetic, Toiletry and Perfumery Association, 2004) .For EEE applications only non-carcinogenic petrolatum should be allowed.

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			CuBe alloys are used in mobile phones in the following applications: Battery Contact, Speaker Contact, EMI Shield Contact, BtoB Connector, FPC Connector, Antenna Contact, SIM Card Connector, Motor Contact, DC Jack Contact, Microphone Contact CuBe alloys are used in PCs in the following applications: I/O connector, BtoB connector, battery contact, burn-in testing socket, mount socket, PCMCIA connector, optical pickup suspension (CD, MD, DVD); Be metal is used as window on high-resolution x-ray machines				
15	Beryllium oxide (BeO)	1304-56-9	In ceramics, as cooling device (ceramic insulator); Thermally conductive electrical insulator		Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	Y	-
16	Antimony trioxide	1309-64-4	Synergist brominated flame retardant Melting agent in special glass, enamel and ceramic manufacture; Fining agent in special glasses; Adherence promoter addition in enamel systems Use in varistor ceramics;	1-7w% 0.1-1.5%	Carc Cat. 3, Xn, R40	N	Draft (Env/HH)

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			Used as catalyst in PET film manufacture	100-300ppm			
17	Antimony compounds	-	Flame retardant; melting agent in CRT glass; solder material (antimony-tin) Melting agent in CRT glass; Dopant in silicon wafer; Used as a yellow pigment for ceramics and plastics	<0.1%wt	Xn; R20/22 N; R51-53	N	Draft (Env/HH)
18	Bisphenol A (4,4'-Isopropylidendiphenol)	80-05-7	Intermediate in polycarbonate and epoxy resin production; Used in the preparation of additive packages for PVC processing; Anti-oxidant in production of plasticizers for use in PVC processing	Residual BPA in epoxy resins and polycarbonate is low, typically <300 ppm per homogeneous material	Repr. Cat. 3; R62 Xi; R37-41 R43 Endocrine disruptor, Cat 1 (according to EDS database)	Y	Final
19	Formaldehyde	50-00-0	Used to make polymers, for example phenolic and melamine resins. Used in printed circuit boards and in lamp cement (bonding glass and base). Also used/found in Ply Wood in Household Appliances, release at high temperature is possible; Insulation finish on copperwire	final polymers and PCBs contain only trace levels	Carc. Cat. 3; R40 T; R23/24/25 C; R34 R43	N	-
20	Nickel[57]	7440-02-0	Used in pigments;		Carc. Cat. 3; R40	N	Draft

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[57] Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH) for those applications where nickel is likely to result in direct and prolonged skin exposure

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			Widely used in lamps both for holder and current carrying parts having no direct skin contact and also for plating parts like Edison bases; Used for plating in automotive and optical special applications further in glass to metal encapsulations. In medicinal products and electronic glass/Metal encapsulations as CrNi-Steel and NiCo-Steel; Metal alloy constituent: CuNi18Zn20 X5CrNi18-10 Used as alloy material in relay contacts and galvanic layers between Cu and e.g. Gold		R43		
21	divanadium pentaoxide; vanadium pentoxide	1314-62-1	Heat detector such as in microbolometers (category 9); Maybe present as constituent in grey pigments and used as flux agent in enamel systems for covering aluminium substrates; Glass, ceramics; Used in special fluorescent lamps with “external ignition strip”. Used as an antistatic material in tapes. May be used as colouring agent in certain special glasses and glass ceramics,	<2500 ppm.	Muta. Cat. 3; R68 Repr. Cat. 3; R63 T; R48/23 Xn; R20/22 Xi; R37 N; R51-53	N	-

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			May be used as a catalyst; Contained in specific ceramic materials				
22	Arsenic / arsenic compounds[58]	7440-38-2	Used as dopant in manufacturing of semiconductor wafers; Semiconductor substrate (e.g. GaAs, GaInAs, GaInAsP, AlGaAs) Adhesion promoter in copper layers of organic chip carriers (including conductive foil); In photodiodes and thermal imaging (WEEE Cat 9); Alloying element in brass e.g. CuZn36Pb2As	<0.1%wt <0.1%wt In foil: ~300 ppm in whole chip carrier: ~20 ppm 0.15%	T; R23/25 N; R50-53	N	-
23	Gallium arsenide[59]	1303-00-0	Semiconductor substrate, dopant in semiconductor material, substrate in LED applications	<0.1%wt		N	-
24	Selenium	7782-49-2	Uses include alloy additive, in glass, light detection semiconductors such as infrared detectors (category 9); Potential large scale application in low-cost solar cells; Colouring agent in certain		T; R23/25 R33 R53	N	-

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[58] Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH)

[59] Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH)

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			special glasses				
25	cobalt oxide	1307-96-6	SmCo Magnets; Maybe present as constituent in black, green and blue pigments and as adherence promoter in enamel systems; Ceramic decoration enamel; It may be used as colouring agent in certain special glasses and radiation shielding applications (e.g. welding), less than 5%. Used in lithium ion batteries, magnets, pigments and catalysts; Blue colorant marking on ceramic insulators; Used with certain ceramic materials for passive components e.g. part of ceramics (varistors, NTC); Used in galvanic processes; Used as colouring agent in certain special glasses, less than 5% e.g. in glass for special lamps (black light blue lamps); Sealing glass for Channel Photo Multiplier		Xn; R22 R43 N; R50-53	N	-
26	cobalt	7440-48-4	Used in special alloys and in electroplated coatings such as NiFeCo;		R42/43 R53		-

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			In NiCo-Steel for glass / metal encapsulations. Used in lithium ion batteries, and in coatings and pigments. Used as a catalyst for film polymerisation in EEE applications. Used in stainless steel as an alloying element; Used in certain ceramic materials in medical devices. Kovar contains 18 % Cobalt and is used in X-ray tubes as typical glass- or ceramic joint metal, for cathode heads and some other parts. In very low amounts as activator in plastic formation. (patient tables) Used as binder in tungsten carbides; Leadframe plating alloy for some semiconductor components Cobalt Silicide (CoSI2) layers deposition in FE manufacturing; Part of alloys in AlNiCo magnets or samarium-cobalt magnet	5-24% of the magnet, the magnet is < 3% w/w of the relay			
27	phenyl bis(2,4,6-trimethylbenzoyl)-phosphine oxide	162881-26-7	Used in X-ray detectors (Categories 8 & 9).		R43 R53	N	-
28	thallium	7440-28-0	Used in HID lamps; Used in certain ceramic materials in medical devices; Contained in AU plating		T+; R26/28 R33 R53	N	-

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			solutions; Dopant used in the manufacture of digital medical x-ray detectors				
29	Rosin; colophony [1]	8050-09-7 [1] 8052-10-6 [2] 73138-82-6 [3]	Used in solder fluxes/pastes; Used in lamp cement (bonding glass and base) and solder materials. Used in manufacture of printed circuit boards. Can be used as a processing aid in the production of polychloroprene elastomers for	< 1% w/w solder in a relay	R43		-

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			wire and cable applications.				
30	Synthetic vitreous fibres[60] -glass fibres - mineral wool - refractory ceramic fibre (RCFs)	142844-00-6 (CAS is only for RCFs; not for all synthetic vitreous fibres)	Glass fibres and mineral wool used as thermal insulation material in ovens, heaters. Used in speciality adhesives and bonding products for EEE; Filler for laminated substrates/ PCB Used to tailor CTE in substrates; Photocell sensor; Glass fiber: used extensively as a reinforcement in plastic. used in epoxy materials for patient tables		RCF: Carc. Cat. 2;		-
31	Bismuth/Bismuth compounds	7440-69-9	solder		-		-
32	DI-N-Octylphthalate (DNOP)[61]	117-84-0	Plasticizer in PVC cables		-	N	-
33	Diisononyl phthalate (DINP)[62]	28553-12-0 and 68515-48-0	Plasticizer in PVC cables		-	N	Final

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[60] Synthetic vitreous fibres are covered by an existing EC marketing of hazardous goods directive. Components containing refractory ceramic fibres as described in Commission Directive 97/69/EC of 5 December 1997, adapting to technical progress Council Directive 67/548/EEC relating to the classification, packaging and labelling of dangerous substances

[61] Restricted for use in toys that can be taken into the mouth by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

[62] Restricted for use in toys that can be taken into the mouth by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
34	1,2-Benzenedicarboxylic acid diisodecyl ester (DIDP)	26761-40-0 and 68515-49-1	Plasticizer in PVC cables		-	N	Final
35	2-ethylhexyl acrylate	103-11-7	2-Ethylhexyl acrylate is used as a monomer in the chemical industry for the production of polymers and copolymers, which are mainly processed further to aqueous polymer dispersions. The polymers and polymer dispersions are used in adhesives and as binders for paints. Other applications include coatings raw materials and uses in the plastics and textiles industries (Used as chemical intermediate)		Xi; R37/38 R43		Final + Comm Recomm.
36	4,4'-methylenedi-o-toluidine	838-88-0	Intermediate for colorants production: may be used to make azo dyes; Used to make dyes but this compound should not be present in products except as impurity. Consider adding to list of azo dyes that are restricted by 76/769/EEC and REACH		Carc. Cat. 2; R45 Xn; R22 R43 N; R50-53		
37	tributyl phosphate	126-73-8	May be used in inks and adhesives, but uncommon or very rare in electrical equipment		Carc.Cat.3; R40 Xn; R22 Xi; R38		
38	nickel sulphate	7786-81-4	Used in electro-less nickel plating to deposit nickel on metallic surfaces and does not remain in EEE products	Carc. Cat. 3; R40 Xn; R22 R42/43 N; R50-53	Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH)		

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
39	Liquid crystals		Electroactive layer in liquid crystal displays of cellular phones, notebooks, PC monitors	0.5g (cell phone, notebook)			
40	Chlorinated hydrocarbons	various	Solvents, cleaning and degreasing agents		Carc.Cat.3; R40		
41	aluminium powder (stabilised)	-	Aluminium metal is used in castings and sheet metal, not in powder form		F; R15 R10		
42	chlorine	7782-50-5	Chlorine compounds used in several applications, mainly related to polymeric materials		T; R23 Xi; R36/37/38 N; R50		
43	red phosphorus	7723-14-0	Flame retardant in certain types of plastics		F; R11 R16 R52-53		
44	magnesium, powder or turnings	-	Magnesium metal is used in castings, not in powder form		F; R11-15		
45	magnesium powder (pyrophoric)	7439-95-4	Magnesium metal is used in castings, not in powder form		F; R15-17		
46	zinc powder - zinc dust (pyrophoric)	7440-66-6	Main use of Zinc in metal alloys, not used in powder form		F; R15-17 N; R50-53		
47	zinc powder - zinc dust (stabilized)	7440-66-6	Main use of Zinc in metal alloys, not used in powder form		N; R50-53		
48	fluorine	7782-41-4	Mainly in fluoropolymers and other fluorine compounds		R7 T+; R26 C; R35		
49	zinc chloride	7646-85-7	Mainly used in the manufacture of certain plastics, residues may exist in these materials at levels below 5000ppm		Xn; R22 C; R34 N; R50-53		
50	white phosphorus	12185-10-3	May be present in certain		F; R17		

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			plastics, metallic- or ceramic materials		T+; R26/28 C; R35 N; R50		
51	barium peroxide	1304-29-6	May be present in certain plastics, metallic- or ceramic materials		O; R8 Xn; R20/22		
52	potassium hydroxide; caustic potash	1310-58-3	May be present in certain plastics, metallic- or ceramic materials		Xn; R22 C; R35		
53	sodium hydroxide; caustic soda	1310-73-2	May be present in certain plastics, metallic- or ceramic materials		C; R35		
54	manganese dioxide	1313-13-9	May be present in certain plastics, metallic- or ceramic materials		Xn; R20/22		
55	molybdenum trioxide	1313-27-5	May be present in certain plastics, metallic- or ceramic materials		Xn; R48/20/22 Xi; R36/37		
56	sodium peroxide	1313-60-6	May be present in certain plastics, metallic- or ceramic materials		O; R8 C; R35		
57	zinc oxide	1314-13-2	May be present in certain plastics, metallic- or ceramic materials		N; R50-53		
58	phosphorus pentoxide	1314-56-3	May be present in certain plastics, metallic- or ceramic materials		C; R35		
59	dicopper oxide; copper (I) oxide	1317-39-1	May be present in certain plastics, metallic- or ceramic materials		Xn; R22 N; 50-53		
60	magnesium hexafluorosilicate	16949-65-8	May be present in certain plastics, metallic- or ceramic		T; R25		

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
			materials				
61	aluminium phosphide	20859-73-8	May be present in certain plastics, metallic- or ceramic materials		F; R15/29 T+; R28 R32 N; R50		
62	sodium carbonate	497-19-8	May be present in certain plastics, metallic- or ceramic materials		Xi; R36		
63	barium carbonate	513-77-9	May be present in certain plastics, metallic- or ceramic materials		Xn; R22		
64	zirconium powder (pyrophoric)	7440-67-7	May be present in certain plastics, metallic- or ceramic materials		F; R15-17		
65	calcium	7440-70-2	May be present in certain plastics, metallic- or ceramic materials		F; R15		
66	zinc sulphate (hydrous) (mono-, hexa- and hepta hydrate); [1] zinc sulphate (anhydrous) [2]	7446-19-7 [1] 7733-02-0 [2]	May be present in certain plastics, metallic- or ceramic materials		Xn; R22 R41 N; R50-53		
67	calcium carbide	75-20-7	May be present in certain plastics, metallic- or ceramic materials		F; R15		
68	copper sulphate	7758-98-7	May be present in certain plastics, metallic- or ceramic materials		Xn; R22 Xi; R36/38 N; R50-53		
69	bromine	7726-95-6	Mostly in flame retardant compounds		T+; R26 C; R35 N; R50		
70	lithium	7439-93-2	Mostly in Li-ion batteries		F; R14/15		

ID	Substance name	CAS-Nr.	Main use in EEE	Quantity	Hazard	REACH SVHC	RAR
					C; R34		
71	Radioactive substances e.g. americium-241		Domestic ionisation chamber smoke detectors (ICSD); measuring devices, dischargers				

9.5 Applicable Laws and Regulations of banned and restricted substances

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
1	Arsenic/arsenic compounds[63]	7440-38-2		T; R23/25 N; R50-53	Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH): 1. Shall not be used as substances and constituents of preparations intended for use: (a) to prevent the fouling by micro-organisms, plants or animals of: – the hulls of boats, – cages, floats, nets and any other appliances or equipment used for fish or shellfish farming, – any totally or partly submerged appliances or equipment; (b) in the preservation of wood. Furthermore, wood so treated shall not be placed on the market; (c) however, by way of derogation: (i) Relating to the substances and preparations in the preservation of wood: these may only be used in industrial installations using vacuum or pressure to impregnate wood if they are solutions of inorganic compounds of the copper, chromium, arsenic (CCA) type C. Wood so treated shall not be placed on the market before fixation of the preservative is completed. (ii) Relating to wood treated with CCA solutions in industrial installations according to point

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[63] Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH)

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					(i): this may be placed on the market for professional and industrial use provided that the structural integrity of the wood is required for human or livestock safety and skin contact by the general public during its service life is unlikely: – as structural timber in public and agricultural buildings, office buildings, and industrial premises, – in bridges and bridgework, – as constructional timber in freshwater areas and brackish waters e.g. jetties and bridges, – as noise barriers, – in avalanche control, – in highway safety fencing and barriers, – as debarked round conifer livestock fence posts, – in earth retaining structures, – as electric power transmission and telecommunications poles, – as underground railway sleepers. Without prejudice to the application of other Community provisions on the classification, packaging and labelling of dangerous substances and preparations, all treated wood placed on the market shall be individually labelled "For professional and industrial installation and use only, contains arsenic". In addition, all wood placed on the market in packs shall also bear a label stating "Wear gloves when handling this wood. Wear a dust mask and eye protection when cutting or otherwise crafting this wood. Waste from this wood shall be treated as hazardous by an authorised undertaking". (iii) Treated wood referred to under points (i) and (ii) shall not be used:

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					– in residential or domestic constructions, whatever the purpose, – in any application where there is a risk of repeated skin contact, – in marine waters, – for agricultural purposes other than for livestock fence posts and structural uses in accordance with point (ii), – in any application where the treated wood may come into contact with intermediate or finished products intended for human and/or animal consumption. 2. Shall not be used as substances and constituents of preparations intended for use in the treatment of industrial waters, irrespective of their use.
2	Bis (2-ethylhexyl) phthalate (DEHP)[64]	117-81-7	Plasticizer in PVC cables	Repr. Cat. 2; R60-61	This is a Water Framework Directive Priority Substance, and is also subject to a comprehensive risk assessment under EC 793/93. Risk management proposals are being prepared by the Swedish rapporteur; Restricted for all toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States

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[64] DEHP is a Water Framework Directive Priority Substance, and is also subject to a comprehensive risk assessment under EC 793/93. Risk management proposals are being prepared by the Swedish rapporteur.

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43
3	Butylbenzylphthalate (BBP)	85-68-7	Plasticizer in PVC cables Encapsulation/potting of electronics components	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	Restricted for all toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43
4	Dibutylphthalate (DBP)	84-74-2	Plasticizer in PVC cables; Encapsulation/potting of electronics components Silber conductive paint for variable resistors	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	Restricted for all toys by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43
5	DI-N-Octylphthalate (DNOP)	117-84-0	Plasticizer in PVC cables		Restricted for toys that can be taken into the mouth by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43
6	Diisononyl phthalate (DINP)	28553-12-0 and 68515-48-0			Restricted for toys that can be taken into the mouth by EC (2005) Directive 2005/84/EC of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles). Official Journal of the European Communities L344, 27.12.2005: 40-43
7	Formaldehyde	50-00-0			German Indoor-Air-limits restricting emissions: Use of “E1” (≤ 0.1 ppm in equilibrium) material would not endanger consumers
8	Nickel	7440-02-0			Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH): 1. Shall not be used: (a) in all post assemblies which are inserted into pierced ears and other pierced parts of the human body unless the rate of nickel release from such post assemblies is less than 0,2 µg/cm2/week (migration limit). (b) in articles intended to come into direct and prolonged contact with the skin such as: – earrings, – necklaces, bracelets and chains, anklets, finger rings, – wrist-watch cases, watch straps and tighteners,

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					– rivet buttons, tighteners, rivets, zippers and metal marks, when these are used in garments, – if the rate of nickel release from the parts of these articles coming into direct and prolonged contact with the skin is greater than 0,5 µg/cm2/week; (c) in articles such as those listed in point (b) where these have a non-nickel coating unless such coating is sufficient to ensure that the rate of nickel release from those parts of such articles coming into direct and prolonged contact with the skin will not exceed 0,5 µg/cm2/week for a period of at least two years of normal use of the article. 2. Articles which are the subject of paragraph 1, shall not be placed on the market unless they conform to the requirements set out in those points. 3. The standards adopted by the European Committee for Standardisation (CEN) shall be used as the test methods for demonstrating the conformity of articles to paragraphs 1 and 2.
9	Nickel dihydroxide	12054-48-7	May be present as constituent in black, yellow and brown pigments and as adherence promoter in enamel systems	Carc. Cat. 3; R40 Xn; R20/22 R43 N; R50-53	Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH)
10	Nickel sulphate	7786-81-4	Used in electro-less nickel plating to deposit nickel on metallic surfaces and does not remain in EEE products	Carc. Cat. 3; R40 Xn; R22 R42/43 N; R50-53	Restricted in EU by 76/769/EEC (item 27 of Annex XVII of REACH)
11	Nonylphenol	25154-52-3			Restricted in EU by 76/769/EEC (item 46 of Annex XVII of REACH) for the following uses: - cleaning - textiles, leather processing - emulsifier in agriculture - metal working

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					- pulp/paper - cosmetic + personal care - co-formulant in pesticides and biocides Nonylphenol has been assessed under EC 793/93 and a wide ranging EU risk reduction strategy has been implemented. It is also a Water Framework Directive Priority Hazardous Substance, and so emissions are meant to be phased out.
12	Perfluorooctane sulfonates	1763-23-1	Photoresists or antireflective coatings		Will be banned by 76/769/EEC (52) (in force on 27th June 2008 except where no alternatives are available[65]
13	PCBs Polychlorinated Biphenyls	1336-36-3 and various others	Not used anymore in electrical equipment		Use restricted by 76/769/EEC and classified as POP, thus banned by Stockholm convention and in EU regulation 850/2004.
14	PCT Polychlorinated Terphenyls	61788-33-8 and various others	Electrical insulation medium, Plasticizers, fire retardants, coatings for electrical wire and cable, dielectric sealants		Already restricted by 76/769/EEC and will also be restricted by REACH (item 1 of Annex XVII).
15	PCN Polychlorinated Naphtalenes	70776-03-3			OSPAR List of Chemicals for priority Action (Update 2007) Restricted in Asia
16	Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	SCCP are no longer used in PVC. Only used during production of EEE – i.e. in metal working (molding, etc), but not in final products.		Regulated by 76/769/EC and REACh Annex XVII (item 27): May not be placed on the market for use as substances or as constituents of other substances or preparations in concentrations higher than 1 %:

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[65] Restriction does not apply to the following applications or processes: 1) photoresists or antireflective coatings for photolithography processes; 2) photographic coatings applied to films, papers, or printing plates; 3) mist suppressants for nondecorative hard chromium (VI) plating; 4) wetting agents for use in controlled electroplating systems

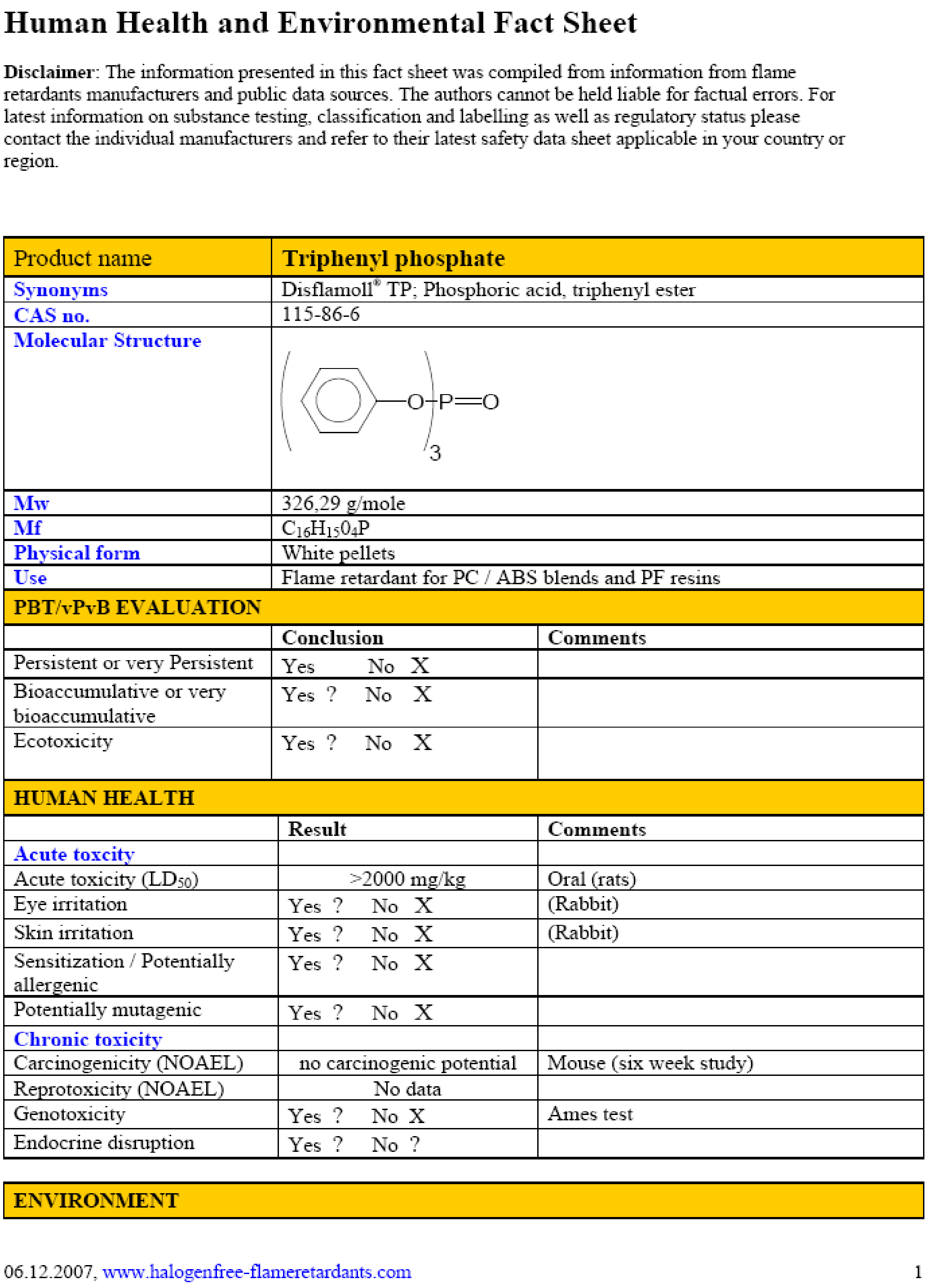
ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					— in metalworking; — for fat liquoring of leather. 2. Before 1 January 2003 all remaining uses of SCCPs will be reviewed by the European Commission, in cooperation with the Member States and the OSPAR Commission, in the light of any relevant new scientific data on risks posed by SCCPs to health and the environment. The European Parliament will be informed of the outcome of this review. This has been assessed under EC 793/93 and an EU risk reduction strategy has been implemented. Further risk management is required now that it has been confirmed PBT substance and POP candidate. It is also a Water Framework Directive Priority Hazardous Substance, and so emissions are meant to be phased out.

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
17	Synthetic vitreous fibres -glass fibres - mineral wool - refractory ceramic fibre (RCFs)	142844-00-6 (CAS is only for RCFs; not for all synthetic vitreous fibres)	Thermal insulation materials in domestic electrical appliances& needed for ovens, heaters, etc		Synthetic vitreous fibres are covered by an existing EC marketing of hazardous goods directive. Components containing refractory ceramic fibres as described in Commission Directive 97/69/EC of 5 December 1997, adapting to technical progress Council Directive 67/548/EEC relating to the classification, packaging and labelling of dangerous substances. Hazard is related to size and shape. Mineral fibers of length < 5 micro meter and diameter of fiber < 3 micro meter when (length of fiber)/(diameter of fiber) > 3. Since the basis of hazard is particle size, this will be difficult to implement in RoHS, where concentration limits are normally used. In some cases the fibre length is sufficient to avoid hazardous characteristics
18	Tributyl Tin (TBT) compounds Triphenyl Tin (TPT) compounds	various	Stabilizer, antioxidant, antibacterial and antifungal agents, antifoulant, antiseptic, anti-fungal agent, paint, pigment, antistaining		Already restricted by 76/769/EC and REACH (item 20 of Annex XVII): 1. Shall not be placed on the market for use as substances and constituents of preparations when acting as biocides in free association paint. 2. Shall not be placed on the market or used as substances and constituents of preparations which act as biocides to prevent the fouling by micro-organisms, plants or animals of: (a) all craft irrespective of their length intended for use in marine, coastal, estuarine and inland waterways and

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
					lakes; (b) cages, floats, nets and any other appliances or equipment used for fish or shellfish farming; (c) any totally or partly submerged appliance or equipment. 3. Shall not be used as substances and constituents of preparations intended for use in the treatment of industrial waters. Tributyltin compounds are listed as a generic entry under the Water Framework Directive as a Priority Hazardous Substance, and so emissions are meant to be phased out.
19	Tributyl Tin Oxide (TBTO)	56-35-9	antiseptic, antifungal agent, paint, pigment, antistaining, refrigerant, foaming agent, extinguishant		Already restricted by 76/769/EC and REACH (item 20 of Annex XVII). Confirmed as a PBT substance by the EU PBT Working Group. No specific restrictions, other than as use as an antifoulant. However, tributyltin compounds are listed as a Water Framework Directive Priority Hazardous Substance, and so emissions are meant to be phased out.
20	Dinickel trioxide	1314-06-3			Already restricted by item 27 of Annex XVII of REACH.
21	Diarsenic trioxide	1327-53-3			Some use restrictions for arsenic compounds by 76/769/EEC (item 19 of Annex XVII of REACH): (please refer to ID3)
22	bromobenzylbromotoluene, mixture of isomers	99688-47-8	Not used anymore in EEE	Xn; R48/22 R43 N; R50-53	EU directive 91/339/EC.

ID	Substance name	CAS-Nr.	Main use in EEE	Hazard	Key legal and regulatory information
23	Asbestos	12001-28-4 132207-32-0 12172-73-5 77536-66-4 77536-68-6 77536-67-5 12001-29-5	Brake lining pad, insulator, filler, abrasive, insulator, filler, pigment, paint, talc, adiabatic material	Carc. Cat. 1; R45 T; R48/23	76/769/EEC, Marketing and Use of Dangerous Substances and amendments: (83/478/EEC; 85/610/EEC; 87/217/EEC; 91/659/EEC; 99/77/EEC)
24	Specific Azocolourants and azodyes (which form certain aromatic amines)	Various	Pigment, dyes, colorants		76/769/EEC, Marketing and Use of Dangerous Substances and amendments: (2002/61/EC; 2003/03/EEC).
25	Ozone Depleting Substances and Hydrochlorofluorocarbons	Various	Refrigerant, foaming agent, insulation extinguishant		Regulation (EC) No. 2037/2000 on substances that deplete the ozone layer

9.6 Human Health and Environmental Fact Sheet for TPP[66]



Human Health and Environmental Fact Sheet

Disclaimer: The information presented in this fact sheet was compiled from information from flame retardants manufacturers and public data sources. The authors cannot be held liable for factual errors. For latest information on substance testing, classification and labelling as well as regulatory status please contact the individual manufacturers and refer to their latest safety data sheet applicable in your country or region.

Product name	**Triphenyl phosphate**
Synonyms	Disflamoll® TP; Phosphoric acid, triphenyl ester
CAS no.	115-86-6
Molecular Structure	(C6H5–O)3P=O, 3
Mw	326,29 g/mole
Mf	$C_{16}H_{15}0_4P$
Physical form	White pellets
Use	Flame retardant for PC / ABS blends and PF resins

PBT/vPvB EVALUATION

	Conclusion	**Comments**
Persistent or very Persistent	Yes No X	
Bioaccumulative or very bioaccumulative	Yes ? No X	
Ecotoxicity	Yes ? No X	

HUMAN HEALTH

	Result	**Comments**
Acute toxcity		
Acute toxicity (LD_{50})	>2000 mg/kg	Oral (rats)
Eye irritation	Yes ? No X	(Rabbit)
Skin irritation	Yes ? No X	(Rabbit)
Sensitization / Potentially allergenic	Yes ? No X	
Potentially mutagenic	Yes ? No X	
Chronic toxicity		
Carcinogenicity (NOAEL)	no carcinogenic potential	Mouse (six week study)
Reprotoxicity (NOAEL)	No data	
Genotoxicity	Yes ? No X	Ames test
Endocrine disruption	Yes ? No ?	

ENVIRONMENT

06.12.2007, www.halogenfree-flameretardants.com 1

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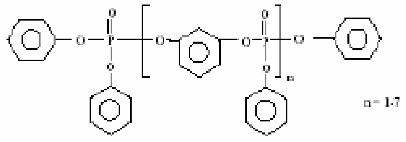
[66] http://www.halogenfree-flameretardants.com/Disflamol_TP.pdf

Degradation		
Half life in water (fresh or marine)	19 days	$t_{1/2}$ at 25°C and pH = 7
Half life in sediment (fresh or marine)		
Half life in soil		
Readily biodegradable	Yes X No	83 – 94 % (28 d)
Inherently biodegradable	Yes ? No X	
Sewage treatment removal	No data	
Bioaccumulation		
BCF	110 - 144	Fish
Log K_{ow}	4,6	Experimental determined
Eco-toxicity		
Chronic toxicity for fish, NOEC	LC_{50} = 0,4 mg/l	96 h
Chronic toxicity for invertebrate, NOEC	EC_{50} = 1,0 mg/l	48 h
Reprotox, invertebrate, NOEC		
Chronic toxicity for algae, NOEC	0,25 – 2,5 mg/l	
Physical properties		
Vapour pressure at 25 °C	< 0,01 hPa at 20 °C	
Solubility in water at 25 °C	approx. 1 ppm	
Soil Adsorption coefficient, K_{oc}		
Henry's law constant (Pa-m^3/mole)		
Hydrolysis (half life) in water		
RISK PHRASES		
	Applies following Directive EC/67/548	Comments
R40	Yes ? No X	
R42	Yes ? No X	
R43	Yes ? No X	
R45	Yes ? No X	
R49	Yes ? No X	
R50	Yes X No	R 50 / 53
R53	Yes X No	R 50 / 53

More information:
www.phosphorous-chemicals.com (LANXESS website)

9.7 Human Health and Environmental Fact Sheet for RDP[67]

Human Health and Environmental Fact Sheet

Product name	**Tetraphenyl resorcinol diphosphate**	
Synonyms	RDP	
CAS no.	125997-21-9	
Molecular Structure		
Mw	574.47 g/mole	
Mf	C30H24O8P2	
Physical form	Liquid	
Use	E.R.	
PBT/vPvB EVALUATION		
	Conclusion	**Comments**
Persistent or very Persistent	Yes No X	Readily biodegradable
Bioaccumulative or very bioaccumulative	Yes No X	Log Kow 4.9, BCF calculation < 1000
Ecotoxicity	Yes No X	Typical acute ecotoxicity > 100 mg/l (WAF)
HUMAN HEALTH		
	Result	**Comments**
Acute toxcity		
Acute toxicity (LD_{50})	LD50 > 5,000 mg/kg bw	Test standard: ....OECD 401.....................................
Eye irritation	Yes No X	Test standard: ....OECD 405.....................................
Skin irritation	Yes No X	Test standard: OECD 404 ....
Sensitization	Yes No X	Test standard: ..OECD 406..
Chronic toxicity		
Carcinogenicity (NOAEL)	No data mg/kg bw	Test standard: ...no toxicity in sub-chronic test 28 days...
Reprotoxicity (NOAEL)	Not reprotoxic mg/kg bw	Test standard: ....OECD 416..................................
Genotoxicity	Yes No X	Test standard: ....Various in vitro/in vivo tests....................................
Endocrine disruption	Yes No X	Method used: Various reprotoxic and

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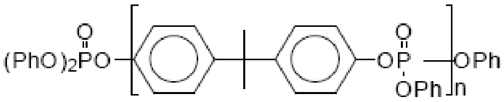
[67] http://www.halogenfree-flameretardants.com/Fyrolflex_RDP.pdf

ENVIRONMENT		
Degradation		
Half life in water (fresh or marine)	< 28 days days	Test standard: ....OECD 301.....
Half life in sediment (fresh or marine)	No data - days	Test standard: ....
Half life in soil	No data - days	Test standard: ....
Readily biodegradable	Yes x No	Test standard : …OECD 301………………………..
Inherently biodegradable	Yes x No	Test standard : …OECD 301 prolonged CBT………………………..
Sewage treatment removal	100 %	Test standard : ……Readily biodegradable EUSES model……………………..
Bioaccumulation		
BCF (log)	< 1000	Species: .....Model BCFWIN.. Test standard: ....
Log K_{ow}	4.9	Test standard: ....OECD 107...
Eco-toxicity		
Chronic toxicity for fish, NOEC	No data - mg/liter	Species: .... Test standard: ....
Chronic toxicity for invertebrate, NOEC	No data - mg/liter	Species: .... Test standard: ....
Chronic toxicity for algae, NOEC	> 100 mg/l mg/liter	Species: ....Ps. Kirchneriella .... Test standard: ....OECD 201..................................
Physical properties		
Vapour pressure at 25 °C	.59x10-3 Pa at 20 deg. C	Test standard: .....OECD 104...
Solubility in water at 25 °C	1.05 mg/liter	Test standard: ....OECD 105....................................
Soil Adsorption coefficient, K_{oc}	No data	Test standard: ....
Henry's law constant (atm-m^3/mole)	No data	Test standard:………………………………
Hydrolysis (half life) in water	17 days	Test standard: ......OECD 111......................................
RISK PHRASES		
	Applies following Directive	Comments
	EC/67/548	
R40	Yes No x	
R42	Yes No x	
R43	Yes No x	
R45	Yes No x	
R49	Yes No x	
R50	Yes No x	
R53	Yes No x	

9.8 Human Health and Environmental Fact Sheet for BDP[68]

Human Health and Environmental Fact Sheet

Product name	**Bisphenol A bis(diphenyl phosphate)**
Synonyms	BDP
CAS no.	5945-33-5
Molecular Structure	
Mw	
Mf	
Physical form	Liquid
Use	E.R.

PBT/vPvB EVALUATION		
	Conclusion	**Comments**
Persistent or very Persistent	Unknown	Not readily
Bioaccumulative or very bioaccumulative	Yes No X	Log Kow 4.5, BCF calculation < 1000
Ecotoxicity	Yes No X	NOEC Chronic Dapnia reprotox test > 1 mg/l

HUMAN HEALTH		
	Result	**Comments**
Acute toxcity		
Acute toxicity (LD_{50})	LD50 > 2,000 mg/kg bw	Test standard: ....OECD 401....................................
Eye irritation	Yes No X	Test standard: ....OECD 405....................................
Skin irritation	Yes No X	Test standard: OECD 404 ....
Sensitization	Yes No X	Test standard: ..OECD 406..
Chronic toxicity		
Carcinogenicity (NOAEL)	No data	Test standard: ...no toxicity in sub-chronic test 28 days...(NOEC 1000 mg/kg/day....................................
Reprotoxicity (NOAEL)	Not data	Test standard: ....
Genotoxicity	Yes No X	Test standard: ....Various in vitro/in vivo tests....................................
Endocrine disruption	No data	Method used: No testing, but not expected based on read-across and structure

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[68] http://www.halogenfree-flameretardants.com/Fyrolflex_BDP.pdf

ENVIRONMENT		
Degradation		
Half life in water (fresh or marine)	No data	Test standard: ....Hydrolysis test indicated half-live > 1 year....
Half life in sediment (fresh or marine)	No data - days	Test standard: ....
Half life in soil	No data - days	Test standard: ....
Readily biodegradable	Yes No x	Test standard : …OECD 301………………………...
Inherently biodegradable	No Data	Test standard : … ………...
Sewage treatment removal	No data	Test standard : …… …...
Bioaccumulation		
BCF (log)	< 1000	Species: .....Model BCFWIN.. Test standard: ....
Log K_{ow}	4.5	Test standard: ....OECD 107.......................................
Eco-toxicity		
Chronic toxicity for fish, NOEC	No data - mg/liter	Species: .... Test standard: ....
Chronic toxicity for invertebrate, NOEC	> 1 mg/liter	Species: ......OECD 202.. Test standard: ....
Chronic toxicity for algae, NOEC	> 1 mg/l mg/liter	Species: ....Ps. Kirchneriella ......max. attainable concentration... Test standard: ....OECD 201..................................
Physical properties		
Vapour pressure at 25 °C	< 1.2 X 10E-3 Pa at 25 C	Test standard: .....OECD 104.......................................
Solubility in water at 25 °C	< 0.5 mg/	Test standard: ....OECD 105....................................
Soil Adsorption coefficient, K_{oc}	> 4.53	Test standard: ....HPLC screening......................................
Henry's law constant (atm-m^3/mole)	No data	Test standard:………………………………
Hydrolysis (half life) in water	> 1 year at pH =7	Test standard: ......OECD 111......................................
RISK PHRASES		
	Applies following Directive EC/67/548	Comments
R40	Yes No x	
R42	Yes No x	
R43	Yes No x	
R45	Yes No x	
R49	Yes No x	
R50	Yes No x	
R53	Yes No x	

9.9 Meetings of Öko-Institut e.V. with different experts during the evaluation process

Date	Location (D)	Topic	Participants
09.11.2007	Frankfurt	Establishment of an inventory of hazardous substances in EEE	Representatives of ZVEI
10.01.2008	Böblingen-Hulb	Establishment of an inventory of hazardous substances in EEE; Banned and restricted substances/materials in EEE	Representatives of Hewlett Packard, Sony and Texas Instruments
13.02.2008	Freiburg	Brominated Flame Retardants; PVC	Representatives of Dell
03.03.2008	Freiburg	Hazardous Substances in Medical Devices (WEEE Cat. 8)	Representatives of COCIR
05.03.2008	Freiburg	Beryllium & Beryllium oxide	Representatives of WVM and Brush Wellman Inc.
18.03.2008	Freiburg	Brominated Flame Retardants	Representatives of EBFRIP