Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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

Contract No. 070307/2007/476836/MAR/G4

Final Report

Freiburg, 17 October 2008

Authors:

Rita Groß
Dr. Dirk Bunke
Carl-Otto Gensch
Stéphanie Zangl
Andreas Manhart

Öko-Institut e.V.
Head Office Freiburg
P.O. Box 50 02 40
79028 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Street Address
Merzhauser Str. 173
79100 Freiburg, Germany

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Novalisstr. 10
10115 Berlin, Germany
Tel. +49 (0) 30 – 28 04 86-80
Fax +49 (0) 30 – 28 04 86-88

The views expressed in this final report are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

The recommendations given by the authors should not be interpreted as a political or legal signal that the Commission intends to take a given action.

Content

Glossary

ABS	Acrylonitrile-butadiene-styrene
AOH	Aluminium-oxide-hydroxide
ATH	Aluminium-tri-hydroxide
ATP	Adaptation to Technical Progress
BBP	Butyl benzyl phthalate
BCF	Bioconcentration factor
BDP	Bis-phenol A bis(diphenyl phosphate)
BFR	Brominated flame retardant
BOM	Bill of material
Carc. Cat	Carcinogenic category 1, 2 or 3
CBD	Chronic beryllium disease
CMR	Cancerogenic, mutagenic and reprotoxic
CRT	Cathode ray tube
CTE	coefficient of thermal expansion
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
EUSES	European Union System for the Evaluation of Substances
HBCDD	Hexabromocyclododecane
HIPS	High impact polystyrene
JIG	Joint Industry Guide
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
PAH	Polycyclic aromatic hydrocarbon

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
PE	Polyethylene
PEI	Polyether imide
PES	Polyethersulfone
POP	Persistent organic pollutants
PP	Polypropylene
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
Tg	glass transition temperature
tpa	Tonnes per year
VCM	Vinyl chloride monomer
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

Executive Summary

Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) prescribes that the European Commission has to review the list of already restricted substances in Article 4 (1) on the basis of scientific facts, taking the precautionary principle into account. Particular attention shall be given to impacts on the environment and human health of other hazardous substances and materials used in electrical and electronic equipment (EEE), and the Commission shall examine the 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 the RoHS Directive.

In this context, DG Environment assigned the present study to provide the Commission with a review of hazardous substances present in EEE, to select candidate substances for a potential inclusion into the RoHS Directive, to evaluate possible substitutes, and to propose policy options for each candidate substance.

This report documents the findings of the study. The results of this study and the recommendations given by the authors should, however, not be interpreted as a political or legal signal that the Commission intends to take a given action.

An inventory of hazardous substances in EEE meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC was established on the basis of data and information provided by manufacturers of EEE. In order to identify substances which are of high relevance for inclusion into the RoHS Directive the following selection criteria were applied on the hazardous substances listed in the inventory:

1. Substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC.
2. Substances meeting the criteria for classification as substances of very high concern (SVHC) in accordance with REACH.
3. Substances which have been found as contaminants in humans and biota.

There are a number of substances not meeting criteria 1 to 3, but nevertheless holding the risk to cause harm to man and the environment during their life cycle. These substances can be described as “potentially dangerous substances”. As an example, substances which can form dangerous degradation or reaction products during their life cycle (e.g. during incineration of waste EEE) are to be considered as “potentially dangerous”. As this property is not expressed through the classification of the substances resp. materials themselves, it has been taken as an additional criterion for the selection process of possible candidate substances:

4. Substances which can form hazardous substances during the collection and treatment of waste electrical and electronic equipment.

Substances meeting the above given criteria have the potential to cause severe harm to humans and/or the environment and have therefore been given the highest priority in this study.

These so-called “high priority hazardous substances” have been further evaluated with regard to their use in EEE, their share of use in EEE with regard to total production volume and the risk for the environment and human health, arising from their use in the different life stages of EEE, as well as findings of these substances in humans, biota and environmental compartments.

Data on substitutes have been collected and the substitutes have been evaluated as far as information on their technical suitability, their (eco-) toxicological and environmental properties was available. The available data suggest that for a large number of applications in EEE, substitutes and/or alternative technologies exist and that the potential adverse effects on environment and human health of the proposed substitutes are less than those of the high priority hazardous substances. However, while hazard classifications exist for most of the substitutes, in many cases comprehensive risk assessments do not. In specific cases, further data and investigations are thus necessary before being able to give a full assessment on the adverse effects of substitutes.

Furthermore, the expected future handling of the identified high priority hazardous substances under the EU legislation on chemicals “REACH” (Regulation EC 1907/2006) has been deduced on basis of their intrinsic properties, production volumes, and use patterns.

An overview on the identified high priority hazardous substances and the main findings for each substance are given in Table 1.

In addition to the substances listed in Table 1, the authors of the present study have considered PVC as well as the group of organobromine and organochlorine substances as potentially hazardous substances. Because PVC is not a substance but a polymer and most of the organobromine/organochlorine substances have not yet been classified as dangerous in accordance with Directive 67/548/EEC[1], their selection is thus going beyond the terms of reference set for the present study. Nevertheless they are considered to fulfil selection criterion 4 because they could lead to the formation and emission of hazardous substances such as organic chlorine compounds, dioxins and furans during incineration of waste EEE.

---

[1] The classification of all organobromine/organochlorine substances has not yet been harmonised at EC level.

Table 1 High priority hazardous substances in EEE

Substance name	**CAS-No.**	**Classific. (Dir 67/548/EEC)**	**REACH SVHC**	**Further hazard potential**	**Quantity used in EEE [t/y in EU]**	**RAR[2] / RRS[3]**	**Information on substitutes**	**REACH candidate list[4]**	**Recommen-dation**
Tetrabromo bisphenol A (TBBP-A)	79-94-7	Proposed classification (on 31st ATP): N; R50-53	-	- DDRP[5] - Detections in biota	40 000 (10 890)[6]	Final ENV/HH; Final RRS	Available	Inclusion unlikely	Inclusion in RoHS
Hexabromo-cyclododecane (HBCDD)	25637-99-4	Proposed classification: N; R50-53 with SCL M = 10[7]	PBT[8]	- DDRP - Detections in biota	210 (3 348)	Final ENV/HH; Final RRS	Available	Inclusion very likely	Inclusion in RoHS
Medium-chained chlorinated paraffins (MCCP)	85535-85-9	R64 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	PBT under evaluation (CSTEE[9] concluded it fulfils PBT criteria) ED Cat 1[10];	- DDRP - Detections in biota	Total use: up to 160 000 however no data available on share of EEE applications	Final ENV/HH; Draft RRS	Available	Inclusion likely	Voluntary phase out; Market surveillance

---

[2] RAR: EU Risk Assessment Report; HH: Human Health Part; ENV.: Environmental Part

[3] RRS: EU Risk Reduction Strategy Document available

[4] REACH candidate list: Candidate substances for a potential inclusion in Annex XIV

[5] DDRP: Formation of dangerous degradation / reaction products during the collection and treatment of EEE

[6] Values in parentheses: Extrapolation of annual flows (bottom-up approach) made during the course of the present study

[7] Specific Concentration Limits with an M factor 10 (proposed by TC C&L)

[8] PBT: persistent and bioaccumulative and toxic substances (EC 2007)

[9] Comité Scientifique de Toxicologie, Ecotoxicologie et l'Environnement (European Scientific Committee on Toxicity, Ecotoxicity and Environment)

[10] Categorisation of the endocrine disrupting activity according to the EU EDS database that was developed within the EU-Strategy for Endocrine Disrupters: http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

Substance name	CAS-No.	Classific. (Dir 67/548/EEC)	REACH SVHC	Further hazard potential	Quantity used in EEE [t/y in EU]	RAR[2] / RRS[3]	Information on substitutes	REACH candidate list[4]	Recommen-dation
Short-chained chlorinated paraffins (SCCP)	85535-84-8	Carc. Cat. 3; R40 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	PBT ED Cat 1	- DDRP - Detections in biota	No reliable data available	Final ENV/HH	Available	Inclusion very likely	Voluntary phase out; Market surveillance
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	CMR (Repr. Cat. 2) ED Cat 1	- Detections in biota	29 000 (18 329)	Final ENV/HH Final RRS	Available	Inclusion very likely	Inclusion in RoHS
Butylbenzyl-phthalate (BBP)	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	CMR (Repr. Cat. 2) ED Cat 1	- Detections in biota	Total use: 19 500 however no data available on share of EEE applications	Final ENV/HH; Final RRS	Available	Inclusion very likely	Inclusion in RoHS
Dibutylphthalate (DBP)	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	CMR (Repr. Cat. 2) ED Cat 1	- Detections in biota	Total use: 14 800 however no data available on share of EEE applications	Final ENV/HH Final RRS	Available	Inclusion very likely	Inclusion in RoHS
Nonylphenol [1] / 4-nonylphenol, branched [2] Nonylphenol ethoxylates	25154-52-3 [1] / 84852-15-3 [2] 9016-45-9	Repr. Cat. 3; R62-63 Xn; R22; C; R34 N;R50-53 Currently not present in Dir. 67/548/EEC.	ED Cat 1 ED Cat 1	- -	No reliable data available	Final ENV/HH Final RRS	Available	Inclusion likely	Voluntary phase out; Market surveillance

Substance name	CAS-No.	Classific. (Dir 67/548/EEC)	REACH SVHC	Further hazard potential	Quantity used in EEE [t/y in EU]	RAR[2] / RRS[3]	Information on substitutes	REACH candidate list[4]	Recommen-dation
Beryllium metal	7440-41-7	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	-	Be metal and composites: 2; Be-containing alloys: 11,5	-	Not investigated in the present study	Inclusion very likely	Labelling
Beryllium oxide (BeO)	1304-56-9	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	-	1,5	-	Not investigated in the present study	Inclusion very likely	Labelling
Antimony trioxide	1309-64-4	Carc Cat. 3, R40	-	- Detections in biota	Total use: 24 250 however no data available on share of EEE applications	Draft ENV/HH	Not investigated in the present study	Inclusion unlikely	Currently no action necessary
Bisphenol A	80-05-7	Repr. Cat. 3; R62 Xi; R37-41 R43 R52 (on adopted 30th ATP, to be published soon)	ED Cat 1	-	Total use: 1 149 870 however no data available on share of EEE applications	Final ENV/HH	Not investigated in the present study	Inclusion likely	Currently no action necessary
Diarsenic trioxide; arsenic trioxide	1327-53-3	Carc. Cat. 1; R45 T+; R28; C; 34 N; R50-53	CMR (Carc. Cat. 1)	-	No data available	-	Not investigated in the present study	Inclusion very likely	Currently no action necessary

Substance name	**CAS-No.**	**Classific. (Dir 67/548/EEC)**	**REACH SVHC**	**Further hazard potential**	**Quantity used in EEE [t/y in EU]**	**RAR[2] / RRS[3]**	**Information on substitutes**	**REACH candidate list[4]**	**Recommen-dation**
Dinickel trioxide	1314-06-3	Proposed classification (on 31st ATP): Carc. Cat. 1; R49 T; R48/23 R43 R53	CMR (Carc. Cat. 1)	-	No data available	-	Not investigated in the present study	Inclusion very likely	Currently no action necessary

Based on the results of the overall evaluation of the high priority hazardous substances, substances have been identified that constitute significant health and environmental risks when used in electrical and electronic equipment. These substances are proposed as candidates for a potential inclusion in RoHS.

The candidate substances for a potential inclusion into the RoHS Directive and the proposed policy option for each candidate are listed in the following table.

Table 2 Proposed policy options for candidate substances

Candidate substance	Proposed policy option and transition period[11]
TBBP-A	Policy option 3[12]: Add TBBP-A for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended for the phase-out of TBBP-A used as additive flame retardant. A transition period of 36 months is recommended for the phase-out of TBBP-A used as reactive flame retardant.
HBCDD	Policy option 4: Add HBCDD for all EEE in the scope of RoHS without exemptions. A transition period of 24 months is recommended.
DEHP	Policy option 3: Add DEHP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.
BBP	Policy option 3: Add BBP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.
DBP	Policy option 3: Add DBP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.

Concerning the recommendations for restrictions on the use of substances made for EEE, two caveats are important:

Firstly, the documented environmental, economic and social data are not complete, in particular for substitutes. For this reason there can be no robust recommendation as to the need to restrict the use of the substances according to the present state of knowledge and the guidelines for impact assessment of the Commission which this study contract must take

---

[11] The transition period is supposed to start after inclusion of any candidate substance in the revised RoHS Directive, i.e. the adoption by the European Parliament and the Council of the European Union of the revised RoHS and its subsequent publication in the Official Journal.

[12] DG Environment elaborated 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 31.

into account. The recommendations made are therefore largely based on the overall judgement, and experience of Öko-Institut e.V.

Secondly, the recommendations to restrict the five substances under the RoHS Directive are not in all cases supported by the conclusions of the official EU risk assessments. This shows the complexity of the policy choice to be made, which must be fully reserved to the discussions of the mandated EU policy makers. This applies even more to the choice between regulatory instruments, e.g. RoHS or REACH, in case a regulation is deemed necessary. The recommendations made in this report must only be understood as one input to making policy choices.

With regard to the assessment of environmental, economic, and social impacts which may occur as a consequence of the proposed policy options, the authors of this study draw the following conclusions:

For the majority of applications of the proposed candidate substances in EEE, substitutes and/or alternative technologies exist on the market. Although most of the possible substitutes have not yet been thoroughly evaluated as to their toxicological effects and environmental impacts, the available data suggest that substitutes are available which are technically viable and pose less risk to human health and the environment than the proposed candidate substances. However, comprehensive risk assessments do not yet exist for most substitutes.

Except for HBCDD it is not out of question that in few certain cases or applications substitution is technically not feasible or may be counterproductive and might lead to negative environmental or health impacts. Therefore, policy option no. 3 is recommended for the proposed candidate substances (except for HBCDD), thus enabling the industry to apply for exemptions for certain applications.

In the context of this study it has been attempted to collect more information on social and economic impacts of substitution triggered by the proposed policy options. Both the stakeholder consultation carried out in the framework of this service contract and the expert workshop held in May 2008 brought questions related to this kind of impacts into focus. Unfortunately, only limited information could be gathered and therefore it was not possible to draw a complete picture of economic and social impacts. This lack of information substantiates that policy option 3 is the most appropriate option for the regulation of TBBP-A, DEHA, BBP and DBP, because whenever substitution is technically or scientifically impractical, exemptions from the legal requirement can be requested.

Three of the discussed high priority hazardous substances, namely MCCPs, SCCPs and nonylphenol/nonylphenol ethoxylates, are only used in small quantities in EEE or by a very limited number of manufacturers. Because of their persistent, bioaccumulating, and toxic properties, these substances should be phased-out from EEE, even more so because safer, less harmful substitutes are available for most of the applications. Nevertheless, an inclusion into the RoHS Directive is not recommended for these substances: Due to their limited applications and/or small quantities used in EEE, the costs arising from their restriction are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. These substances bring about certain health and environmental risks when used in EEE, but these risks are not considered to be significant due to the limited amount of these substances used in EEE. A restriction of these substances by their inclusion into the RoHS Directive is considered to be disproportionate. Nevertheless, industry should phase-out these substances from the remaining few applications voluntarily by substitution with safer, less harmful alternatives. Furthermore, the inclusion of MCCPs, SCCPs and nonylphenol/nonylphenol ethoxylates in market surveillance programmes is recommended in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase.

For beryllium and beryllium oxide the following measures are proposed to support the safe recycling of beryllium-containing EEE:

- EEE containing Beryllium and beryllium oxide 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.

PVC as well as the group of organobromine and organochlorine substances cannot be proposed as candidate substances for a potential inclusion in RoHS. PVC does not meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC and substances classified in the organobromine and organochlorine list need to be further investigated on a case by case basis. They are thus beyond the terms of reference set for the present study.

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)[13] 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, as far as data are available;
- Policy options for each substance considered as a candidate for an inclusion into the RoHS Directive.

---

[13] 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.

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 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 took 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 at 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 has been carried out by the Öko-Institut e.V. between October 2007 and June 2008. The project tasks were 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.

In Chapter 3, the hazardous substances contained in EEE are characterised and discussed in detail with regard to their hazard classification, their use in EEE, the legislations under which the substances are currently managed, and the risk for the environment and human health arising from the use of the hazardous substances in the different life stages of EEE. Chapter 4 summarises information on substitutes to the identified potential candidate substances. In Chapter 5, the facts that argue for or against an inclusion of the potential candidate substances in RoHS are discussed. In Chapter 6 a link is made to the new regulation on chemicals (REACH), and policy options are elaborated for each candidate substance. An outlook on further research needs and activities within the electronic industry is given in Chapter 7.

2 Inventory of other hazardous substances in EEE

2.1 Definition of 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. These criteria are summarised in Section 9.1.

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 within the EU. This list is regularly updated through adaptations to technical progress, with the 30th Amendment to Technical Progress[14] (ATP) adopted and to be published soon. Some of the substances fulfilling the criteria for classification as dangerous have not yet been included in the present ATP of Annex I to Directive 67/548/EEC, but their inclusion in Annex I is officially proposed e.g. in the EU Risk Assessment Reports, or they have been included in the draft consultation list of the 30th and 31st Adaptation to Technical Progress (ATP) of Directive 67/548/EEC.

In the present study it has further been checked whether the substances that meet the criteria for classification as dangerous do also fulfil the criteria for PBT/vPvB substances, and/or meet the criteria for evidence of endocrine disruption.

---

[14] 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

The EU Working Group on PBT substances[15] has set up a list of so-called PBT (persistent and bioaccumulative and toxic) as well as vPvB (very persistent and very bioaccumulative) substances (EC 2007). The criteria for identification of PBT/vPvB substances are set in the Technical Guidance Document (2003)[16] and in Annex XIII of Regulation (EC) No 1907/2006 (REACH Regulation)[17]. The numeric criteria for PBT and vPvB substances are summarised in Section 9.2.

In order to address the potential environmental and health impacts of endocrine disruption, in 1999 the European Community adopted a “Community Strategy for Endocrine Disrupters”. 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)[18].

In addition to the hazardous substances described above, there are a number of substances not meeting the criteria for classification as dangerous, but nevertheless bearing the risk to cause harm to man and the environment during their life cycle. These substances can be described as “potentially dangerous substances”. Examples for this are substances which can form dangerous degradation or reaction products during their life cycle e.g. during incineration of waste EEE.

2.2 Selection criteria

From the information sources described in the following chapter data on a large number of hazardous substances used in the manufacture of EEE have been gathered. These substances differ broadly regarding their hazardous potential, their existence in EEE and their regulatory status.

Only those substances have been considered as substances for further investigation that nowadays are still used in the manufacture of electrical & electronic components and that are

---

[15] 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.

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

[17] 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

[18] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

present in the final product. Thus, process chemicals that are used during the manufacture of EEE but that are not present in the final products were outside the scope of the study.

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 meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC**
   In accordance with the terms of reference of the present study, those substances have been selected for further evaluation that meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC (c.f. Section 9.1 of this report). These substances are listed in Annex I to Directive 67/548/EEC (30th ATP, adopted and to be published soon)[19]. Some of the substances fulfilling the criteria for classification as dangerous have not yet been included in the present Adaptation to Technical Progress (ATP) of Annex I to Directive 67/548/EEC, but their inclusion in Annex I is proposed in the EU Risk Assessment Reports and/or they have been included in the draft consultation list of the 31st Adaptation to Technical Progress (ATP) of Directive 67/548/EEC.

   The timescale for implementation of the 31st ATP is the 1st of June 2009. The proposed EC Regulation to adopt the Globally Harmonised System of Classification (GHS) in the EU is expected to be agreed before this date. This Regulation will take the existing Annex I of Dangerous Substances Directive, together with all the adaptations to technical progress (including the 31st ATP), and convert the entries to GHS classifications and labels. These will be then inserted in a new Annex that will act directly at EU level. Member States will not need to implement the 31st ATP into national legislation. For substances that are not classified in Annex I to Directive 67/548/EEC it is the duty of the manufacturer/ importer to assess chemicals prior to their marketing on the basis of available information in accordance with Annex VI to Directive 67/548/EEC.

   For substances that are not (yet) classified in Annex I to Directive 67/548/EEC it is the duty of the manufacturer / importer to assess chemicals prior to their marketing on the basis of available information in accordance with Annex VI to Directive 67/548/EEC[20].

---

[19] Corrigendum to Commission Directive 2004/73/EC of xxx (to be published soon) adapting to technical progress for the 30th 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

[20] Annex VI of Directive 67/548/EEC: General classification and labelling requirements for dangerous substances and preparations. Official Journal No L 225/263, 21/08/2001.

Not all substances that meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC are of relevance to EEE. Furthermore, several of these substances have already been regulated by RoHS or by Marketing and Use Restrictions Directive 76/769/EEC. Therefore, the inventory of hazardous substances was shortened to those substances that may be relevant for EEE by sorting out those substances that

- 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;
- have already been regulated by RoHS (lead, mercury, cadmium, hexavalent chromium, PBB and PBDE).

For the remaining substances meeting criterion 1, their classification and intrinsic properties according to the chemicals' legislation REACH (Regulation 1907/2006) have been considered and it has been evaluated whether the substances would be regarded as substances of very high concern (SVHC) in the sense of REACH. Thus, the second criterion for the identification of substances which are of high relevance for inclusion into the RoHS Directive is as follows:

2. **Substances meeting the criteria for classification as substances of very high concern (SVHC) in accordance with 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 67/548/EEC;

   (b) substances meeting the criteria for classification as mutagenic category 1 or 2 in accordance with Directive 67/548/EEC;

   (c) substances meeting the criteria for classification as toxic for reproduction category 1 or 2 in accordance with Directive 67/548/EEC;

   (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;

(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.[21]

An indication on bioaccumulation and persistence of a substance is not only given by laboratory studies but also by findings of the substance in humans/biota and environmental compartments. Substances identified in humans and biota raise concern regarding potential long-term harmful effects and, if detected in remote areas, regarding long-range transport. Findings of a substance in top predators furthermore indicate a bioaccumulation in the food chain. Therefore, a third criterion was defined in order to identify those dangerous substances which are of high relevance for inclusion into the RoHS Directive:

3. **Substances which have been found as contaminants in humans and biota.**
   These substances not necessarily fulfil the strict criteria for bioaccumulation and persistence as given in Annex XIII of REACH. These properties are at present not expressed by the R-phrases of Directive 67/548/EEC, 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).

---

[21] 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.

Substances which fulfil criterion 1 together with one of the criteria 2 or 3 have the potential to cause severe harm to humans and/or the environment and have been selected for further evaluation in the present study.

There are a number of substances not meeting criteria 1-3, but nevertheless holding the risk to cause harm to man and the environment during their life cycle. These substances can be described as "potentially dangerous substances". Examples for this are substances which can form dangerous degradation or reaction products during their life cycle e.g. during incineration of waste EEE.

This property is not expressed by the classification of the substances resp. materials themselves. Therefore it is been taken as an additional criterion in the selection process:

4. **Substances which can form hazardous substances during the collection and treatment of electrical and electronic equipment.**
   The terms of reference of the present study prescribe that indications should be examined about the risks for environment and human health arising from the use of the identified hazardous substances in EEE at the various stages of the life cycle of the product – production, use, and in particular end of life management of the equipment in which the hazardous substances are contained[22]. This task refers firstly to those substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC being used in EEE. However, against the background that the Thematic Strategy on the Prevention and Recycling of Waste[23] introduces "life cycle thinking" into waste policy, potentially dangerous substances which may form dangerous degradation or reaction products during their life cycle have also been evaluated in the present study.

Figure 1 gives an overview on the selection criteria applied. Substances meeting criterion 2 and/or 3 are in any case a subset of substances meeting criterion 1. Substances forming dangerous degradation / reaction products (criterion 4) are partly a subset of substances meeting criterion 1. Nevertheless there are other substances meeting criterion 4 which do not meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC. Independent of this situation all substances fulfilling these criteria have the potential to cause severe harm to humans and/or the environment. Therefore, they have been given the highest priority in this study.

---

[22] See „Specifications to invitation to tender DG Env.G.4/ETU/2007/0070r", page 4, Task 3a

[23] COM (2005) 666 final from 21.12.2005

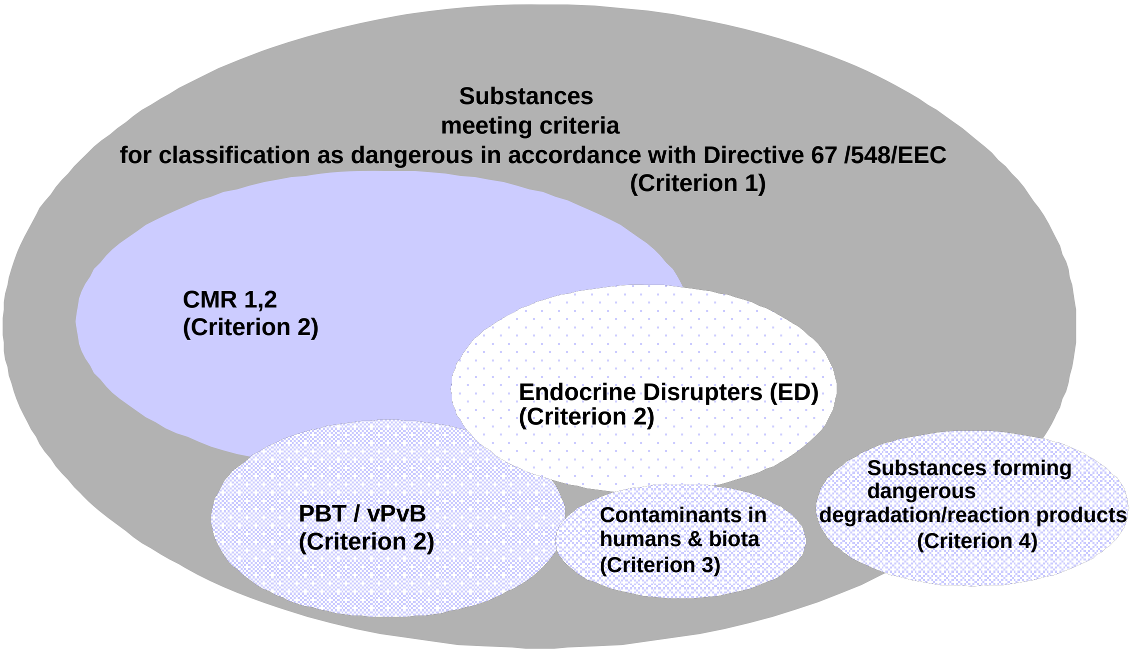


Figure 1 Overview on selection criteria

Substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC (criterion 1) but not fulfilling one of the other criteria 2-4 were considered to have a lower hazardous potential. These substances have been documented in the inventory of hazardous substances in EEE (see Section 9.5) but have not been further evaluated.

A large number of hazardous substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC have already been regulated by other European legislation. It has been checked whether the existing regulations refer explicitly to the use in EEE. Applicable Laws and Regulations of regulated (i.e. banned and restricted) substances used in EEE are presented in Section 9.6.

2.3 Information sources

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

- In a stakeholder consultation, manufacturers and suppliers of EEE were asked to specify which hazardous substances/materials are present 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.
- 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 (literature data).
- Study reports on hazardous substances in EEE and related documents.
- Companies' lists of banned and restricted substances.
- Expert talks with manufacturers, NGOs and research institutes; an overview of all meetings is given in Section 9.8 in the Annex.

2.3.1 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, 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 Specifications published by the German Electrical and Electronic Manufacturers Association (ZVEI). This component structure is presented in Section 9.3. Manufacturers and suppliers of EEE were asked to identify those electrical and electronic components that they produce/supply and to specify which hazardous substances (meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC) are contained in the specified typical components. Furthermore they were asked to 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 9.4.

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 from 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 2.3.2, 2.3.3, and 2.3.4). 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 fulfilling the selection criteria 1 to 4 defined in Section 2.2 were allocated a high priority. The resulting preliminary 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 any 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 these substances need a further in-depth evaluation.

The list of the 46 high priority substances and all comments received on these 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)”.

2.3.2 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*

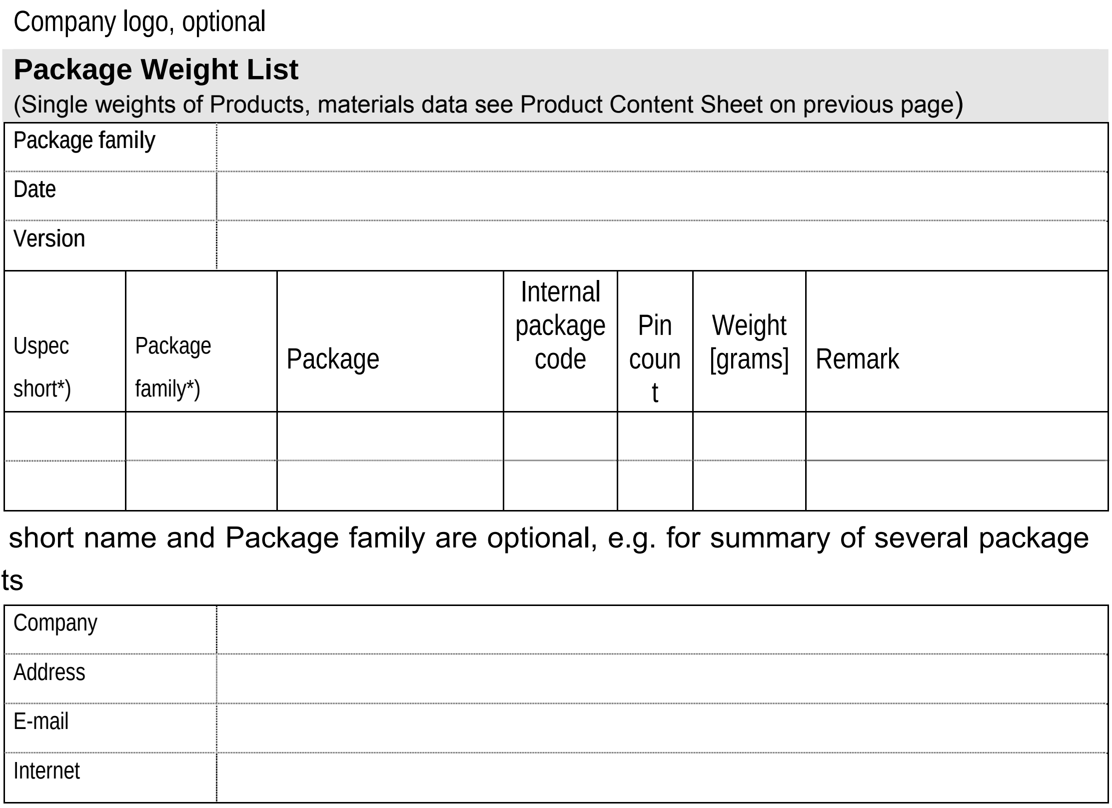
**) optional

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 2 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:

Table 3 Electrical and electronic components covered by Umbrella specification

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)

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 personal statements from experts, the Umbrella specifications are not internationally accepted.

For some of the component families not covered by the specifications other sources of information 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 had to be made in order to allocate hazardous substances to the electrical and electronic components (see Section 2.6).

2.3.3 XRF analysis

X-ray fluorescence analysis is an established and harmonized screening method for the qualitative and quantitative determination of elements in (solid) samples and is therefore suited to test the elemental composition of electrical and electronic equipment. XRF analysis is used by market surveillance authorities as well as companies to check RoHS compliance of EEE.

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 analysed 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 analysed: 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 4 summarizes the data for some components of electrical and electronic equipment. 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.

Table 4 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 / 1 380	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 / 1 037	-	1 / 2	-	-	-	1 285 / 1 837	21 / 27	61 /75
Capacitor/condenser (plastic)	-	-	-	-	166 982 / 297 574	-	-	-	-	-	7 / 10	-
Core of the transformer	20 059 / 31 650	3 131 / 3 894	17 643 / 35 178	-	-	-	-	-	-	853 / 1 061	0 / 112	-

2.3.4 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: 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

I) prohibits their use;
II) restricts their use; or
III) 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:

I) Materials/substances that are of significant environmental, health, or safety interest;

II) Materials/substances that would trigger hazardous waste management requirements;

III) 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.

2.4 Inventory of hazardous substances and materials in EEE and identification of high priority hazardous substances

Based on the information sources described in Section 2.3 an inventory of hazardous substances in EEE meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC was established (cf. Section 9.5 of this report). This inventory contains 64 substances and substance groups (e.g. short-chained chlorinated paraffins).

All these substances fulfil the first selection criterion described in Section 2.2 (classification as dangerous in accordance with Directive 67/548/EEC).

By application of selection criteria 2 and 3, from the inventory 14 substances have been selected as high priority hazardous substances. Table 5 lists the names and CAS numbers of these substances as well as their main use in EEE and their quantities in electrical and electronic components (as far as this information is available). 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.

Table 6 lists potentially dangerous substances which do not meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC, but which nevertheless hold the risk to cause harm to man and the environment during their life cycle e.g. by the formation of dangerous degradation or reaction products, especially regarding the circumstances of recycling and disposal practices in Asia and Africa (see Section 2.6 of this report). These substances are beyond the terms of reference set for the present study. However, due to the potential risk for human health and environment arising from the use of these substances and their ubiquitous application in EEE, they should not be neglected and are therefore treated as a separate additional group of hazardous substances in the present study.

Table 5 High priority hazardous substances (meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC) in EEE

Substance name	CAS-No.	Classification (Dir 67/548/EEC)	REACH SVHC	Further hazard potential	Main use in EEE	Quantity used in EEE [t/y in EU]
Tetrabromo bisphenol A (TBBP-A)	79-94-7	Proposed classification (on 31st ATP): N; R50-53	-	Dangerous degr. products Detections in biota	Reactive FR in epoxy and polycarbonate resin, Additive FR in ABS	40 000
Hexabromocyclododecane (HBCDD)	25637-99-4	Proposed classification: N; R50-53 with SCL M = 10[24]	PBT[25]	Dangerous degr. products Detections in biota	Flame retardant in HIPS, e.g. in audio-visual equipment, wire, cables	210
Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	R64 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	ED Cat 1[26]; PBT under evaluation (CSTEE[27] concluded it fulfils PBT criteria)	Dangerous degr. products Detections in biota	Secondary plasticizers in PVC; flame retardants	Total use: up to 160 000 however no data available on share of EEE applications
Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	Carc. Cat. 3; R40 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	ED Cat 1 PBT	Dangerous degr. products Detections in biota	Flame retardant	No reliable data available

---

[24] Specific Concentration Limits with an M factor 10 (proposed by TC C&L); for M factor see http://ecb.jrc.it/classlab/6599a33_S_SCL.doc

[25] PBT: persistent and bioaccumulative and toxic substances (EC 2007)

[26] Categorisation of the endocrine disrupting activity according to the EU EDS database that was developed within the EU-Strategy for Endocrine Disrupters: http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

[27] Comité Scientifique de Toxicologie, Ecotoxicologie et l'Environnement (European Scientific Committee on Toxicity, Ecotoxicity and Environment)

Substance name	CAS-No.	Classification (Dir 67/548/EEC)	REACH SVHC	Further hazard potential	Main use in EEE	Quantity used in EEE [t/y in EU]
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	CMR (Repr. Cat. 2) ED Cat. 1	Detections in biota	Plasticizer in PVC cables; Encapsulation/potting of electronic components	29 000
Butylbenzylphthalate (BBP)	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	CMR (Repr. Cat. 2) ED Cat. 1	Detections in biota	Plasticizer in PVC cables Encapsulation/potting of electronic components	Total use: 19 500 however no data available on share of EEE applications
Dibutylphthalate (DBP)	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	CMR (Repr. Cat. 2) ED Cat. 1	Detections in biota	Plasticizer in PVC cables; Encapsulation/potting of electronics components Silber conductive paint for variable resistors	Total use: 14 800 however no data available on share of EEE applications
Nonylphenol [1] / 4-nonylphenol, branched [2]	25154-52-3 [1] / 84852-15-3 [2]	Repr. Cat. 3; R62-63 Xn; R22; C; R34 N;R50-53	ED Cat. 1	-	Surfactants used in coatings for films in EEE and in formulations to clean printed circuit boards; adhesives	No reliable data available
Nonylphenol ethoxylates	9016-45-9	Currently not present in Dir. 67/548/EEC.	ED Cat. 1			
Beryllium metal	7440-41-7	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	-	Beryllium metal and composites: - Optical instruments, - X-ray windows; Beryllium-containing alloys: - Current carrying springs, - Integrated circuitry sockets	Be metal and composites: 2; Be-containing alloys: 11,5
Beryllium oxide (BeO)	1304-56-9	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	-	BeO ceramic applications: Laser bores and tubes	1,5

Substance name	CAS-No.	Classification (Dir 67/548/EEC)	REACH SVHC	Further hazard potential	Main use in EEE	Quantity used in EEE [t/y in EU]
Antimony trioxide	1309-64-4	Carc Cat. 3, R40	No	Detections in biota	Synergist brominated flame retardant Melting and fining agent in special glass, enamel and ceramic manufacture	Total use: 24 250 however no data available on share of EEE applications
Bisphenol A (4,4'-Isopropylidendiphenol)	80-05-7	Repr. Cat. 3; R62 Xi; R37-41 R43 R52 (on adopted 30th ATP, to be published soon)	ED Cat. 1	-	Intermediate in polycarbonate and epoxy resin production	Total use: 1 149 870 however no data available on share of EEE applications
Diarsenic trioxide; arsenic trioxide	1327-53-3	Carc. Cat. 1; R45 T+; R28; C; 34 N; R50-53	CMR (Carc. Cat. 1)	-	Fining agent in certain special glasses and glass ceramics	No data available
Dinickel trioxide	1314-06-3	Proposed classification (on 31st ATP): Carc. Cat. 1; R49 T; R48/23 R43 R53	CMR (Carc. Cat. 1)	-	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)	No data available

Table 6 Hazardous substances (not meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC) in EEE

Substance name	**CAS-No.**	**Classification (Dir 67/548/EEC)**	**REACH SVHC**	**Further hazard potential**	**Main use in EEE**	**Quantity used in EEE [t/y in EU]**
Organochlorine and organobromine compounds	See Table 21	Substance specific	-	Dangerous degr. products	Flame retardants	No data available
PVC	9002-86-2	Not classified	-	Dangerous degr. products	Cables & wires	ca. 385 000

2.5 Inventory for selected hazardous substances

In the previous Section 2.4 of this report for some of the hazardous substances data on the annual quantity used in EEE applications are reported on the basis of information given in EU RAR. These data are mainly derived from the use pattern of the substances; the procedure is frequently called a top-down approach.

In addition to the top-down approach, an estimation of the annual flow has been made for those substances listed Table 5 and Table 6 for which sufficient data on quantities had been available from literature. This procedure can be called a bottom-up approach. This approach and the results are described in the following sub-sections.

2.5.1 Allocation of hazardous substances to electrical and electronic components

The following Figure 3 describes the procedure how the hazardous substances identified in the previous section could be allocated to the most important electrical and electronic components.

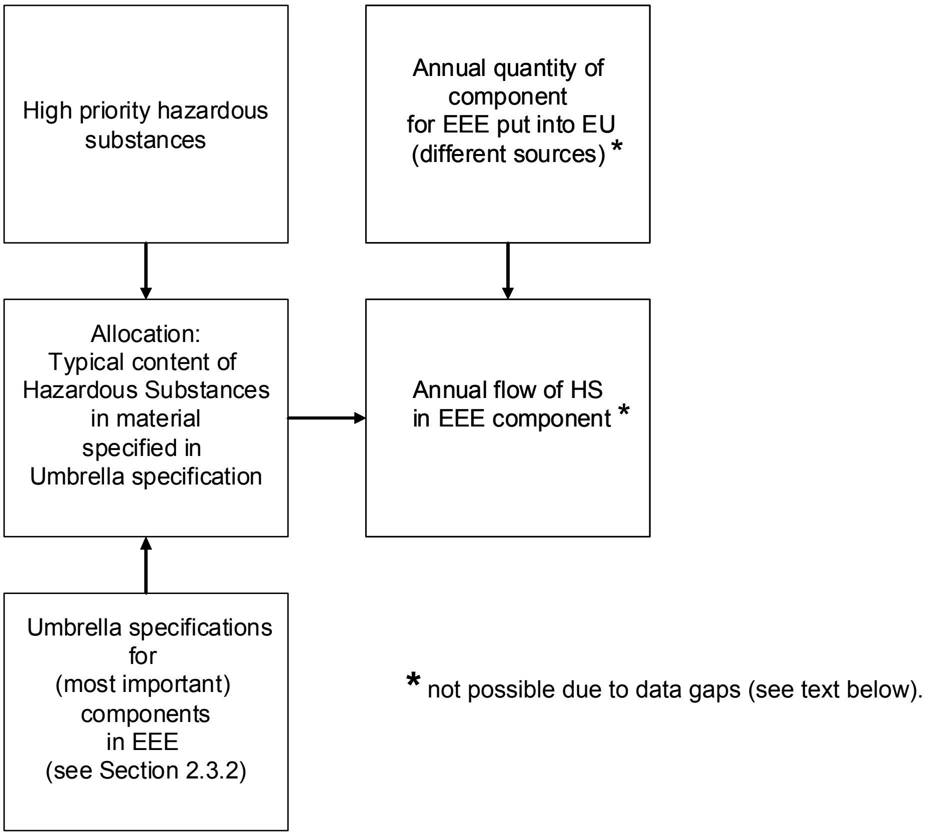


Figure 3 Allocation of hazardous substances to electrical and electronic components

The following Table 7 exemplarily shows the allocation procedure for three components. Due to the large volume the overall list was placed into the annex of this report (c.f. Section 9.7).

Table 7 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%
…	…	....	....	....	....

In order to relate the content of the selected hazardous substances to the material data given in the umbrella specifications the following assumptions have been made:

- The mean TBBP-A content in epoxy resin was estimated to be 34%.
- The mean concentration of HBCDD in HIPS was assumed to be 4%.
- For soft PVC it was assumed that the content of the three phthalates DEHP, BBP, DBP together accounts for 40%.

Unfortunately it was not possible to get input data on the annual quantity of the components put onto the EU market, as the aggregation level of the statistics to be used for this kind of calculation differs considerably. Furthermore it is nearly impossible to assign the specifications used by the ZVEI on the one hand to the data entries of statistics on the other hand. Against this background the (rough) estimation of the annual quantities was done at the level of EEE products and not at the level of components.

2.5.2 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 bills of materials (BOM) are available through preparatory studies under the EuP directive. The following figure illustrates the procedure:

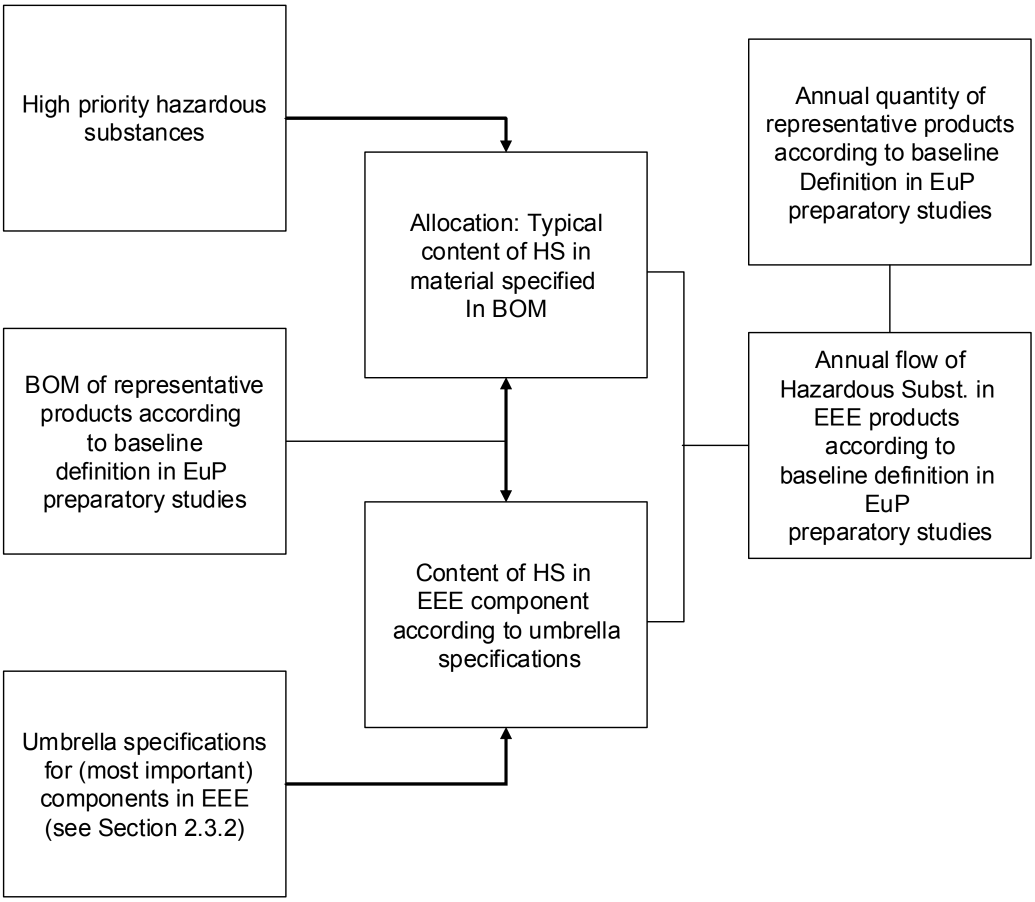


Figure 4 Allocation of hazardous substances to typical EEE products

The level of detail used in the EuP preparatory studies is higher than the level used in the umbrella specifications. Therefore it was necessary to define a typical electronic assembly in order to specify the content of hazardous substances in electronic components and in controller boards of EEE products, respectively.

The definition of this virtual assembled printed circuit board was based on own experiences. It should be kept in mind that this definition is only valid for a very rough estimation of the magnitudes of hazardous substances present in EEE products.

Table 8 Definition of the virtual assembled printed circuit board (Size: 100mm * 100mm)

Subgroup / Typical Components	**TBBP-A**	**HBCDD**	**DEHP, BBP, DBP**	**PVC (incl. Phthalates)**	**Typical weight**
PCB 6 lay; 4,5 kg/m²	11,65%	-	-	-	33 g
1 Leaded resistor, fusible	0,34%	-	-	-	-
4 Resistors, Radial mounted power film	-	-	-	-	40 g
90 SMD Flat chip	0,27%	-	-	-	1 g
6 Aluminium Electrolytic Capacitor (radial)	-	-	?	1,65%	48 g
3 Metallised Film Capacitor (Boxed)	6,80%	-	-	-	15 g
26 Tantalum Capacitor (SMD)	6,43%	-	-	-	7 g
36 Surface mount devices medium power transistors	4,34%	-	-	-	50 g
14 Surface mount diode in melf packages	0,24%	-	-	-	1 g
2 Thin quad flat packages	6,91%	-	-	-	1 g
1 Connector Plastic Housing	0,44%	-	-	1,00%	100 g
Virtual PCB, mounted	**7,94 g**	**-**	**-**	**1,79 g**	**296 g**

The results of the allocation of hazardous substances to EEE products can be seen in the following table. According to the state of the preparatory studies, only for typical examples of the most important products data are available.

Table 9 Selected hazardous substance in EEE products covered by EuP preparatory studies

WEEE-Cat	Product	TBBP-A	HBCDD	DEHP, BBP, DBP	PVC (incl. Phthalates)	Typical weight	**Source of data** EuP Preparatory Study:
		[g]				**[kg]**	
1	Washing machines	4,63	-	92,82	232,64	72,31	"WM 5 kg"
	Dishwashers	62,81	-	191,46	480,48	50,70	"DW 12 ps"
	Boilers	18,51	-	0,74	4,18	45,40	"Boiler Size M"
	Water heater	6,39	-	9,45	24,44	3,56	"Electric instantaneous - M"
	Refrigerators	6,30	-	141,09	353,52	44,34	"Cold 1"
	Refrigerator-freezer	8,14	-	142,44	357,14	61,71	"Cold 7"
	Upright freezer	9,25	-	215,33	539,49	53,24	"Cold 8"
2	External power supplies	0,53	-	9,30	23,32	0,10	"Personal Care Product's EPS"
	External power supplies	3,78	-	0,15	0,85	0,32	"Standard Battery Charger"
3	Desktop PC	70,70	-	1,49	8,43	12,79	"Desktop PC"
	Laptop	25,54	-	10,18	28,53	3,77	"Laptop"
	LCD display	7,26	-	17,49	44,64	6,81	"17" LCD display"
	CRT display	9,20	-	17,97	46,08	16,40	"17" CRT display"
	EP-Copier / MFD monochr.	75,88	69,06	2,66	15,04	68,14	"EP Copier MFD mono"
	EP-Copier / MFD colour	72,36	-	39,47	103,93	143,45	"EP Copier MFD mono"
	EP-Printer / SFD monochr.	35,26	-	77,36	196,18	23,10	"EP-Printer / SFD monochrome"
	EP-Printer / SFD colour	41,12	13,20	92,12	235,47	43,10	"EP-Printer / SFD colour"
	IJ-Printer / MFD Personal	14,84	93,38	0,51	2,90	9,36	"IJ-Printer / MFD Personal"
	External power supplies	2,30	-	6,93	17,61	0,18	"Printer EPS"
	External power supplies	2,56	-	14,08	35,51	0,27	"Average EPS for Laptops of 65 W"
	External power supplies	4,69	-	17,79	45,06	0,40	"Average EPS for Laptops of 90 W"
	External power supplies	0,85	-	7,47	18,79	0,10	"Average Mobile Phone"
	External power supplies	5,27	-	5,41	14,19	0,30	"Average DECT Phone"
	External power supplies	0,53	-	9,30	23,32	0,10	"Set-top box / Modem EPS"
4	32" LCD-TV	61,34	-	22,24	63,33	23,16	"32" LCD-TV"
	42"PDP-TV	83,77	-	95,62	249,59	45,91	"42" PDP-TV"
	29"CRT-TV	76,45	-	90,65	236,24	45,54	"29"CRT-TV"
	Simple Digital TV Converters (Simple Set Top Boxes)	5,56	-	9,82	25,25	1,22	"Simple STBs""
	External power supplies	0,78	-	0,03	0,18	0,10	"Digital Camera EPS"

5	Fluorescent lamps	0,49	-	0,02	0,11	71,00	"Compact Fluorescent Lamp with integrated ballast"
	Electromagnetic gear	3,48	-	0,01	0,07	0,84	"Magnetic ballast for LFL T8-36W"
	Electronic ballasts	5,39	-	0,21	1,22	0,49	"Electronic ballast for 2*FL T8-36W"
	External power supplies	94,56	-	1,06	5,99	1,27	"Transformer for Halogen Lighting"
	External power supplies	3,41	-	3,34	8,77	0,23	"Halogen Lighting Transformer (electronic)"
6	External power supplies	9,57	-	11,17	29,13	0,60	"Power Tool Charger"

2.5.3 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 figure illustrates the procedure:

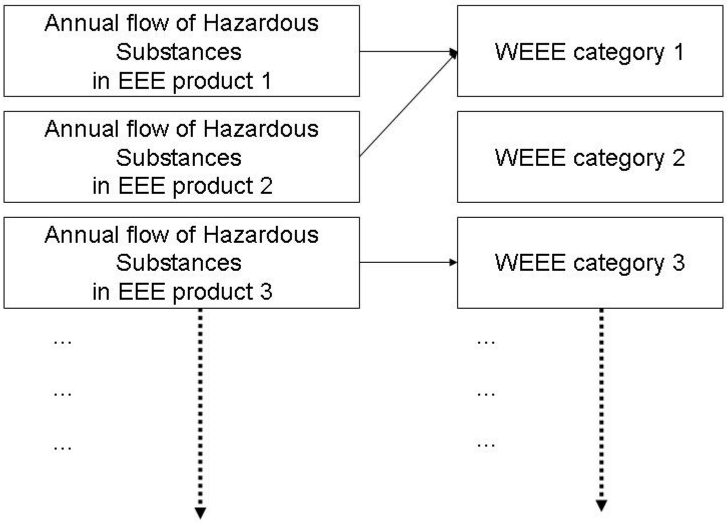


Figure 5 Allocation of EEE products to WEEE categories

However, this level of inventory could 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 10 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 large appliances used for cooking and other processing of food, electric heating appliances, electric radiators, other large appliances for heating rooms, beds, seating furniture, electric fans, air conditioner appliances, other fanning, exhaust ventilation and conditioning equipment	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, coffee machines and equipment for opening or sealing containers or packages; electric knives; appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances; clocks, watches and equipment for the purpose of measuring, indicating or registering time; scales	External power supplies; (vacuum cleaners)
3	IT and telecommunications equipment	Centralised data processing; mainframes; minicomputers; printer units; personal computing; personal computers, including the CPU, mouse and keyboard; laptop computers, including the CPU, mouse and keyboard; notebook computers; notepad computers; printers; copying equipment, electrical and electronic typewriters, pocket and desk calculators, and other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means	Desktop PC; Laptop; LCD display; CRT display; EP-Copier/MFD and SFD, 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 distribution of sound and image than by telecommunications	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 spreading or controlling light with the exception of filament bulbs	External Power Supplies; Fluorescent lamps; Electromagnetic gear; Electronic ballasts; Luminaires

WEEE Category #	**(WEEE) Category title**	**Products**	**BOM of products available (EuP preparatory studies)**
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 screwing or removing rivets, nails, screws or similar uses; tools for welding, soldering or similar use; equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means; tools for mowing or other gardening activities	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)	Radiotherapy equipment; cardiology; dialysis; pulmonary ventilators; nuclear medicine; laboratory equipment for in-vitro diagnosis; analysers; freezers; fertilization tests; other appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability	-
9	Monitoring and control instruments	Smoke detector; heating regulators; thermostats; measuring, weighing or adjusting appliances for household or as laboratory equipment; other monitoring and control instruments used in industrial installations (e.g. in control panels)	-
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

Based on the data of annual input on EU market or stock, respectively, an extrapolation was made for the most relevant EEE products. The results are shown in the following table. Although due to data gaps only a minor number of EEE products could be included in the estimation and notwithstanding the simplifications which had to be made, the total amounts are in the same order of magnitude as the results for the substances summarised in Table 5.

Table 11 Extrapolation of annual flows of selected substances for most relevant EEE products

WEEE-Cat	**Product**	**EU-Consumption / Stock Data**		**TBBP-A**	**HBCDD**	**DEHP, BBP, DBP**	**PVC (incl. Phthalates)**
		Million units		**Tonnes**			
1	Washing machines	29,10	Consumpt.	135	-	2 701	6 770
	Dishwashers	13,00	Consumpt.	817	-	2 489	6 246
	Boilers	7,00	Consumpt.	130	-	5	29
	Water heater	10,00	Consumpt.	64	-	95	244
	Refrigerators	14,00	Consumpt.	88	-	1 975	4 949
	Refrigerator-freezer	2,00	Consumpt.	16	-	285	714
	Upright freezer	2,00	Consumpt.	18	-	431	1 079
3	Desktop PC	30,00	Consumpt.	2 121	-	45	253
	Laptop	31,00	Consumpt.	792	-	315	884
	LCD display	38,00	Consumpt.	276	-	665	1 696
	CRT display	2,00	Consumpt.	18	-	36	92
	EP-Copier / MFD monochr.	5,97	Stock	453	412	16	90
	EP-Copier / MFD colour	0,38	Stock	27	-	15	39
	EP-Printer / SFD monochr.	14,74	Stock	520	-	1 140	2 892
	EP-Printer / SFD colour	68,41	Stock	2 813	903	6 302	16 109
	IJ-Printer / MFD Personal	21,76	Stock	323	2 032	11	63
4	32" LCD-TV	17,53	Consumpt.	1 075	-	390	1 110
	42"PDP-TV	3,89	Consumpt.	326	-	372	971
	29"CRT-TV	11,49	Consumpt.	878	-	1 042	2 714
			Total	**10 890**	**3 348**	**18 329**	**46 946**

2.6 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. Rather, a large fraction of EEE is shipped as second-hand goods to non-EU countries where it will eventually end up as waste.

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 a minimum of 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% of the waste potential (see Table 12), which means that the currently installed collection system and treatment is only partly able to manage the European WEEE-volume.

Table 12 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%

#	Treatment category	Current % collected of WEEE arising
6	Electrical and electronic tools	20,8%
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. 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).

2.6.1 References

- Buchert, M., Hermann, A., Jenseit, W., Stahl, H. et al. (2007): Verbesserung der Edelmetallkreisläufe: Analyse der Exportströme von Gebraucht-Pkw und -Elektro-(nik)geräten am Hamburger Hafen. Öko-Institut, Darmstadt.
- Darby, L. & Obara, L. (2005): Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. In: Resources, Conservation and Recycling, 44(1): 17-35.
- Hicks, C, Dietmar, R & Eugster, M. (2005): The recycling and disposal of electrical and electronic waste in China - legislative and market response. In: Environmental Impact Assessment Review 25 (2005): 459-471.
- Huismann, J., Magalini, F., Kuehr, R., Maurer, C., Ogilvie, S., Poll; J., Delgado, C., Artim, E., Szezak, J. & Stevels, A. (2007): 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE). UNU, Bonn.
- Manhart, A. (2007): Key social impacts of electronics production and WEEE-recycling in China. Öko-Institut, Freiburg.
- Osibanjo, O. & Nnorom, I.C. (2007): The challenge of electronic waste (e-waste) management in developing countries. Waste Management Research 25 (6): 489-501.

- Puckett, J., Westervelt, S., Gutierrez, R. & Takamiya, Y. (2005): The digital dump: Exporting re-use and abuse to Africa. Basel Action Network (BAN), Seattle.

3 Characterisation of hazardous substances

Substances which meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC and fulfil the further selection criteria defined in Section 2.2 have the potential to cause severe harm to humans and/or the environment. These so-called "high priority substances", listed in Table 5 and Table 6, have been further evaluated. In the following section the high priority hazardous substances are characterised and discussed (as far as information is available) with regard to

- their classification: Directive 67/548/EEC; CMR; PBT / vPvB; endocrine disruption potential; SVHC;
- their use in EEE;
- the legislations under which the substances are currently managed;
- the risk for the environment and human health arising from the use of the hazardous substances in the different life stages of EEE;
- risk assessment conclusions and risk reduction strategies recommended by the Risk Reduction Strategy Meeting of the Member States

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)[28]. The current EU risk assessment procedure is mainly based on a quantitative approach: for all relevant applications of a substance the estimated or measured exposure data are put into relation with determined effect data resulting in a risk quotient. If this risk quotient is below 1 (i.e. the predicted concentration e.g. at the workplace or in the environment is lower than the concentration that causes a negative effect) the application is considered to be "safe" with regard to human health or the environment. For safe applications there is no need for further information and/or testing or for risk reduction measures beyond those which are being applied.

In the course of setting up the new chemicals regulation REACH substances have been identified for which a quantitative risk assessment methodology may not be sufficient to establish "safe" concentrations in the environment (ECHA 2008). Examples for this type of

---

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

substances are so called PBT (persistent, bioaccumulative and toxic) and vPvB (very persistent and very bioaccumulative) substances.

PBT/vPvB substances can give rise to specific concerns that may arise due to their potential to accumulate in parts of the environment and

- that the effects of such accumulation are unpredictable in the long-term;
- such accumulation is practically difficult to reverse as cessation of emission will not necessarily result in a reduction in chemical concentration.

Furthermore, PBT or vPvB substances may have the potential to contaminate remote areas that should be protected from further contamination by hazardous substances resulting from human activity because the intrinsic value of pristine environments should be protected.

These specific concerns occur particularly with substances that can be shown both to persist for long periods and to bioaccumulate in biota and which can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain. In case of vPvB chemicals, there is concern that even if no toxicity is demonstrated in laboratory testing, long-term effects might be possible since high but unpredictable levels may be reached in man or the environment over extended time periods.

Similar to the situation for PBT/vPvB, a “safe” concentration without risk can also not be obtained for substances of chronic toxicity which exert their effects by a non-threshold mode of action.

Risk management measures must minimise exposures and emissions to humans and the environment that result from manufacture or uses throughout the lifecycle of these substances. However, even if it can be shown that emissions of these substances from uses are limited, it still needs to be considered that the substances may eventually enter the environment e.g. during the waste stage. In order to reduce the exposure of humans and the environment to these substances as far as possible, substances of very high concern should therefore be replaced by less hazardous substances wherever it is possible (REACH Article 55).

3.1 Tetrabromobisphenol-A (TBBP-A)

3.1.1 Classification

TBBP-A meets the criteria for classification as dangerous in accordance with Directive 67/548/EEC. It is not yet listed on Annex I to Directive 67/548/EEC. However, TBBP-A is included in the draft consultation list of the 31st Adaptation to Technical Progress (ATP) of

Directive 67/548/EEC. The proposed classification for TBBP-A in relation to environmental effects is as follows:

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

For substances that are not classified in Annex I to Directive 67/548/EEC it is the duty of the manufacturer/ importer to assess chemicals prior to their marketing on the basis of available information in accordance with Annex VI to Directive 67/548/EEC. The self-classification by industry for TBBP-A is in agreement with the proposed classification in the draft consultation list of the 31st ATP of Directive 67/548/EEC.

Manufacturers of TBBP-A are in the process of updating their safety data sheets (SDS) to include the new classification in accordance to Annex VI to Directive 67/548/EEC and partly have already included the proposed classification in TBBP-A fact sheets[29].

Endocrine disruption

There are indications of potential effects on the endocrine system in some *in vitro* tests with aquatic organisms (EU RAR TBBP-A 2007). 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[30]). 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.

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 available monitoring data presented in the EU RAR TBBP-A (2007) suggest

---

[29] http://www.cefic-efra.org/pdf/PDF_Fact/tbbpa.pdf

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

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 Faroe Islands; see Table 13). The T criterion is not met.

SVHC

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

3.1.2 Use

TBBP-A is the most widely used brominated flame retardant (FR) 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 (figures are based on data for 2003/2005). 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/y for finished products and components.

Reactive flame retardant

TBBP-A is primarily used in the manufacture of flame-retarded epoxy and polycarbonate resins. When used as reactive flame retardant it is covalently bound in the polymer and becomes a constituent of the base material. Leaching out of the molecule or vaporising is thus 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 encapsulate 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 or evaporate 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.

3.1.3 Current legislation

- 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 EU / national regulations cover the management of waste from electrical and electronic products or incineration in general:
  - Directive 2002/96/EC (WEEE Directive) prescribes that plastics containing brominated flame retardants have to be removed from any separately collected WEEE and shall be disposed of or recovered in compliance with Article 4 of Council Directive 75/442/EEC.
  - 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/m^3 (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 (SFT 2007a & SFT 2007b).
- On European level TBBP-A has been proposed by the European Parliament to be included in the list of priority substances of the Water Framework Directive, however the final compromise package adopted by the European Institutions finally rejected the substance as priority substance.
- EU RAR in accordance with Council Regulation (EEC) 793/93 (repealed by the REACH Regulation)

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).

3.1.4 Risk assessment

Environment

The data and information presented in this chapter derive from the draft EU RAR of TBBP-A, (Part I - environment 2007). The environmental part of the EU RAR of TBBP-A had been finalised in 2008, however, the final version has not yet been published up to time of preparing the present report. Therefore, the following data have been taken from the publicly available draft EU RAR (2007).

For sources other than the EU RAR, respective references are given.

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 is 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 (EU RAR 2007).

The total amount of TBBP-A present in new products (either as an additive or reacted into the polymer backbone) is estimated to be approximately 40 000 tonnes/year in the EU. About 90% of the TBBP-A in finished products is used in reactive applications and 10% is used in additive applications.

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. The amount of TBBP-A present as an additive in finished products is 4 000 tonnes/year. Release from EEE is also possible for the use as reactive flame retardant in case TBBP-A is not completely reacted into the polymer backbone, but present as residual monomer. In the EU RAR it is assumed that a maximum of 0,06% of TBBP-A used as 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.

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.

Loss from volatilisation of TBBP-A is mainly relevant for its use as additive flame retardant. 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 contrast, the potential for volatilisation of TBBP-A from plastics where it is used as a reactive flame retardant is considered to be very low. Only in cases where TBBP-A is present as residual monomer volatilisation may occur over extended time periods.

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 the TBBP-A could volatilise to the atmosphere or leach out of the plastic into groundwater. It is currently not 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 itself from incineration processes will be very low. 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 is concluded in the EU RAR that TBBP-A, as a source of bromine, can contribute to the formation of halogenated dibenzo-p-dioxins and dibenzofurans generated during such processes.

Monitoring

Monitoring data in the EU RAR of TBBP-A show that findings of TBBP-A in environmental compartments, biota and humans are not restricted to industrial or urban regions (Table 13); TBBP-A is also found in more remote regions including the Arctic. For example, TBBP-A has been detected in eleven out of eleven samples of moss from Norway and this is thought to suggest that transport via the atmosphere could be a possibility (the distance to the nearest village/town was at least 10 km for these samples). There is also a report that TBBP-A was present in an air filter sample taken from the Russian Arctic. 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.

TBBP-A has also been detected in human breast milk from the Faroe Islands at levels up to 11 µg/kg lipid.

With regard to the findings of TBBP-A in the Arctic, de Witt et al. (2006) conclude that there are indications that TBBP-A may behave as a POP but there are too few data as yet to reach firm conclusions and more research is needed to fill these data gaps. These indications include TBBP-A findings in the Arctic and indications of long-range transport.

Table 13 Measured values of TBBP-A in environmental compartments, biota and humans (EU RAR TBBP-A, 2007)

Levels in environmental compartments		
Surface water	< 0,001 – 0,020	µg/L
Sediment	< 0,1 – 270 (9752)	µg/kg dry weight
Soil	< 0,1	µg/kg dry weight
Sewage sludge	< 0,1 – 192 (600)	µg/kg dry weight
Levels in biota (selection)		
Eel (Berlin)	0,045 – 0,10	µg/kg wet weight
Fish (Norway)	0,01 – 0,18	µg/kg wet weight
Cod liver (North Sea)	0,35-1,73	µg/kg wet weight
Whiting (fillet)	97 - 245	µg/kg lipid
Star fish (UK Estuaries)	4,5	µg/kg wet weight
Hermit crab (North Sea)	< 1 – 35	µg/kg lipid
Harbour porpoise, blubber (North Sea)	6 – 35	µg/kg wet weight
Cormorant liver (UK)	0,07 – 10,9	µg/kg wet weight
Predatory birds' eggs (Norway)	< 0,004 – 0,013	µg/kg wet weight
Levels in humans		
Human blood serum	< 0,1 – 10	µg/kg lipid
Human breast milk	< 0,01 – 11	µg/kg lipid

In parentheses: extremely high single value

In addition to the monitoring data presented in the EU RAR of TBBP-A, further findings of TBBP-A in tissues of humans, dolphins, and sharks are reported by Johnson-Restrepo et al. (2008). Concentrations of TBBP-A in human adipose tissue obtained in New York City, and in three top-level marine predators, namely, bull shark, Atlantic sharpnose shark, and bottlenose dolphin, all collected from Florida coastal waters between 1991 and 2004.

The highest concentration of TBBP-A found in human tissues was 0,464 µg/kg lipid wt. Concentrations of TBBP-A in muscle tissues from two shark species and bubbler from dolphins collected from the coastal waters of Florida are reported in Table 14.

The highest concentrations of TBBP-A was found in muscle tissues from bull shark (35,6 µg/kg lipid wt).

Table 14 Measured values of TBBP-A in biota (Johnson-Restrepo et al. 2008)

Species	**No. of samples**	**Tissue**	**Location**	**Year**	**TBBP-A [µg/kg lipid wt]**	
Bottlenose dolphin	4	Blubber	West coast of Florida	1991–1996	Mean	0,451
					Range	0,056–1,53
					% Positive	100
	5	Blubber	West coast of Florida	2000–2001	Mean	1,86
					Range	0,1–8,48
					% Positive	100
	6	Blubber	East coast of Florida	2001–2004	Mean	1,18
					Range	0,094–6,15
					% Positive	100
Bull shark	6	Muscle	East coast of Florida	1993–1994	Mean	5,17
					Range	4,17–8,07
					% Positive	100
	7	Muscle	East coast of Florida	2002–2004	Mean	13,2
					Range	0,035–35,6
					% Positive	100
Atlantic sharpnose shark	3	Muscle	East coast of Florida	2004	Mean	0,872
					Range	0,495–1,43
					% Positive	100

Conclusions of Risk Reduction Strategy Meeting: Environment

The 14th Risk Reduction Strategy Meeting (EU Commission 2007) has drawn the following conclusions within the draft recommendation appendices for TBBP-A:

The conclusion of the assessment of the risks to the

ATMOSPHERE

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to the
AQUATIC AND TERRESTRIAL ECOSYSTEM is

1. that there is a need for further information and/or testing. This conclusion is reached because:
    - it is possible that TBBP-A may be degraded to bisphenol-A during anaerobic sewage sludge treatment processes (which could lead to bisphenol-A being applied to soil), or in anaerobic freshwater and marine sediments. These conclusions should be reconsidered once future aquatic and terrestrial effects data will be generated and the corresponding PNECs for bisphenol-A will be determined.
    - another possible metabolite/degradation product – tetrabromobisphenol-A bis(methyl ether) – possibly meets the screening criteria for a PBT substance. Although the results from present studies are inconclusive, it is suggested that it is a very minor degradation product. Given that a need for risk reduction measures has already been identified for some uses (which should reduce the environmental burden of the parent compound), no further specific work is recommended to address this issue at the present time.
    - the risk characterisation ratios for the marine environment indicate a possible risk from some applications. The need for further toxicity data with marine organisms should be evaluated once the implications of any risk reduction activities resulting from the assessment for fresh water and freshwater sediment are known.

    The collection of additional information should, however, not delay the implementation of appropriate control measures needed to address the concerns related to other endpoints (conclusion (i) on hold).

2. that there is a need for specific measures to limit the risks. This conclusion is reached because:
    - the PEC/PNEC is >1 for surface water and sediment at compounding sites where TBBP-A is used as an additive flame retardant in ABS (acrylonitrile-butadiene-styrene resins).
    - the PEC/PNEC is >1 for the terrestrial compartment, where TBBP-A is used as an additive flame retardant in ABS from compounding and conversion sites. The conclusion for conversion sites is dependent on whether or not sewage sludge from the site is applied to agricultural land (no risk is identified where sewage sludge is not applied to land). For ABS compounding sites a risk is identified regardless of the assumptions made over the spreading of sewage sludge.

The conclusion of the assessment of the risks to

MICRO-ORGANISMS IN THE SEWAGE TREATMENT PLANT

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

During the Risk Reduction Strategy Meeting the following strategy for limiting risks have been proposed:

Competent authorities in the Member States concerned should lay down, in the permits issued under Council Directive 96/61/EC[31], conditions, emission limit values or equivalent parameters or technical measures regarding TBBP-A in order for the installations concerned to operate according to the best available techniques (hereinafter "BAT") taking into account the technical characteristic of the installations concerned, their geographical location and the local environmental conditions.

Local emissions to the environment of TBBP-A should, where necessary, be controlled by national rules to ensure that no risk for the environment is expected.

Human health

The data and information presented in this chapter derive from the EU RAR of TBBP-A, (Part II – human health 2006). For sources other than the EU RAR, respective references are given.

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.

---

[31] Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control, OJ L 257, 10.10.1996, p. 26.

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, are 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. These data also show there is potential for exposure of neonates via mother's milk. However, it is not possible to point out specific sources to the TBBP-A exposure and to extrapolate the actual exposure levels of the individuals or to evaluate the degree of bioavailability from the exposure.

Conclusions of Risk Reduction Strategy Meeting: Human health

The 14th Risk Reduction Strategy Meeting (EU Commission 2007) has drawn the following conclusions within the draft recommendation appendices for TBBP-A:

The conclusion of the assessment of the risks to workers, consumers and humans exposed via the environment is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to human health (arising from physico-chemical properties) is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

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 waste EEE are disposed of to landfills or – to a smaller extent – incinerated.

For disposal by incineration and landfill, metal recycling and accidental fires, it is concluded in the EU RAR that TBBP-A, as a source of bromine, can contribute to the formation of halogenated dibenzo-p-dioxins and furans generated during such processes but it is not possible to quantify the amounts or assess the environmental significance of these products.

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 TBBP-A containing material enters the recycling process.

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.

3.1.5 Partial conclusion on TBBP-A

TBBP-A is very toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment. Furthermore, TBBP-A is considered to be persistent (P) or potentially very persistent (vP) and thus, may accumulate in the environment. A final conclusion on its endocrine disruption potential could not yet be drawn.

Based on the available data in the EU RAR the Risk Reduction Strategy Meeting has come to the conclusion that concerning human health there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. The risk assessments in the EU RAR show that risks to workers, consumers and humans exposed via the environment are not expected by the use of TBBP-A as additive or reactive flame retardant. Concerning the environment, however, there is a need for further information and/or testing, and there is a need for measures to limit the risk for aquatic compartments including sediment and terrestrial compartments. The latter conclusion is reached because there is a possible risk from some applications of TBBP-A as additive flame retardant.

In the EU RAR the risk to human health and the environment was estimated by applying quantitative risk assessment methodologies meaning that predicted environmental concentrations (PEC) are related to predicted no-effect concentrations (PNEC). If the resulting risk quotients are below 1, the risk is considered to be acceptable as it is the case for most applications of TBBP-A.

Concerning the findings of TBBP-A in biota as for example in predatory birds' eggs in Norway the EU RAR concluded that the presence of a synthetic substance in the tissues of top predators is clearly undesirable, but does not by itself necessarily constitute a risk. The significance of the levels detected in predatory bird eggs was considered in the EU RAR to be low. The conclusion was drawn that there is therefore currently no reason for concern, even in the absence of information on trends.

TBBP-A has been found in samples of human breast milk, indicating that neonates may be specifically exposed to TBBP-A via mother's milk. However, the EU RAR concludes on basis of a quantitative risk assessment that concerning the risk for infants there is at present no need for risk reduction measures beyond those which are being applied already.

More recent finding of TBBP-A in humans and three top-level marine predators have not yet been included in the EU RAR. The fact that TBBP-A, which is persistent and very toxic to aquatic organisms, has been detected in top-level marine predators needs to be taken into account for further evaluations. These findings indicate that TBBP-A has a certain bioaccumulation potential in aquatic species; this is also reflected by the relatively high BCF value of TBBP-A. According to the new Guidance for the implementation of REACH (ECHA 2008), substances that can be shown both to persist for long periods and to bioaccumulate in biota and which can cause toxic effects after a longer time and over a greater spatial scale give rise to specific concern. Due to their persistence they have the potential to accumulate in parts of the environment. The effects of such accumulation are unpredictable in the long-term and such accumulation is practically difficult to reverse. It is concluded in the Guidance for the implementation of REACH that these properties may lead to an increased uncertainty in the estimation of risk to human health and the environment when applying quantitative risk assessment methodologies. For substances with persistent, bioaccumulating and toxic properties a "safe" concentration in the environment cannot be established using the methods currently available with sufficient reliability for an acceptable risk to be determined in a quantitative way.

Concerning the potential formation of dioxins and furans through incineration of TBBP-A containing materials, the EU RAR concluded that emission control technology is available for incinerators and metal recycling in Europe reducing the amounts of these substances formed in the process to acceptable levels. Shipment of used and obsolete electrical and electronic equipment containing TBBP-A 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 are not taking into account in the EU RAR.

Despite of the comprehensive risk assessment presented in the EU RAR there are concerns regarding the findings of TBBP-A in species at the top of the food chain with unknown long-term effects. Further concerns arise from the possible formation of dioxins and furans under uncontrolled incineration conditions and in countries without advanced emission control technology like many Asian and African countries where a considerable amount of used and obsolete EEE is shipped. These aspects have not or only partly be taken into account in the EU RAR of TBBP-A. On basis of these potential risks for the environment and human health TBBP-A is considered as a potential candidate for an inclusion in RoHS.

3.1.6 References

- de Witt, C. et al. (2006): Levels and trends of brominated flame retardants in the Arctic; Chemosphere 64 (2006) 209-233.
- ECHA European Chemicals Agency (2008): Guidance for the implementation of REACH: Guidance on information requirements and chemical safety assessment; Chapter R.11: PBT Assessment.
- EU Risk Assessment Report 2,2',6,6'-Tetrabromo-4,4'-Isopropylidene Diphenol (Tetrabromobisphenol-A), Final Environmental Draft (2007).
- EU Risk Assessment Report 2,2',6,6'-Tetrabromo-4,4'-Isopropylidenediphenol (Tetrabromobisphenol-A or TBBP-A), Part II – Human Health, Final Report (2006).
- EU Commission (2007): The 14th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Ccontrol of Risks of Existing Substances (23/24 October 2007); Subject: Draft Recommendation Appendices for Tetrabromobisphenol A (TBBPA); Doc: ES/20c/2007.
- Johnson-Restrepo, B. et al. (2008): Tetrabromobisphenol A (TBBPA) and hexabromocyclododecanes (HBCDs) in tissues of humans, dolphins, and sharks from the United States; Chemosphere 70 (2008) 1935–1944.
- 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 Classification

HBCDD meets the criteria for classification as dangerous in accordance with Directive 67/548/EEC. It is not yet listed on Annex I to Directive 67/548/EEC, however, the proposed classification for HBCDD in relation to environmental effects as indicated in the EU RAR (2007) is as follows:

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

The self-classification by industry for HBCDD in accordance to Annex VI to Directive 67/548/EEC is in agreement with the proposed classification in the EU RAR (2007).

In addition, the TC C&L proposed Specific Concentration Limits with an M factor 10[32].

Manufacturers of HBCDD are in the process of updating their safety data sheets (SDS) to include the new classification and have already included the proposed classification in HBCDD fact sheets[33].

Endocrine disruption

According to some in vitro and in vivo tests presented in the EU RAR of HBCDD (2007), 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[34].

PBT and vPvB evaluation

HBCDD does not unequivocally fulfil the specific P-criterion, with some reliable studies indicating that biodegradation can occur. It does however not degrade rapidly and monitoring data indicate a significant degree of environmental transport and overall stability. The BCF of HBCDD is 18 100 and thus the vB criterion is fulfilled. Also the T-criterion is fulfilled according to available data. HBCDD is ubiquitous in the environment, being also found in remote areas far away from point sources. The highest concentrations of HBCDD are

---

[32] M factor: see http://ecb.jrc.it/classlab/6599a33_S_SCL.doc

[33] http://www.flameretardants.eu/Objects/2/Files/HBCDFactsheet.pdf

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

detected in marine top-predators such as porpoise and seals showing that HBCDD bioaccumulates up the food chain. Based on an overall assessment the TCNES subgroup on identification of PBT and vPvB substances have concluded that HBCDD has PBT properties according to the PBT criteria of the TGD.

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. However, SCHER opinion has been requested and confirmatory studies are awaited."

SVHC

To the current standard of knowledge, HBCDD meets the criteria of a substance of very high concern as defined by REACH.

The European Chemicals Agency ECHA has published an Annex XV dossier for HBCDD with a proposal for identification of HBCDD as a SVHC (Sweden 2008a). Within this dossier it is proposed to identify HBCDD as a PBT according to REACH Article 57 (d).

3.2.2 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 9 600 tonnes/year. The EEE relevant use of HIPS contributes 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.

3.2.3 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).
- EU RAR in accordance with Council Regulation (EEC) 793/93
- Annex XV dossier prepared by Sweden (2008)

3.2.4 Risk assessment

The data and information presented in this chapter derive from the final draft EU RAR of HBCDD (October 2007). The EU RAR of HBCDD had been finalised in 2008, however, the final version has not yet been published up to time of preparing the present report. Therefore, the following data have been taken from the publicly available final draft EU RAR (2007).

For sources other than the EU RAR, respective references are given.

Environment

Exposure

The EU RAR contains 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.

EEE relevant polymer end-products containing HBCDD accumulate on landfill sites and may 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. During formulation and use of HIPS emissions to the air, wastewater and surface water are released.

Monitoring

A large set of data on measured concentrations in biota are available and have been presented comprehensively in the EU RAR (2007). In the following, only a small part of that information is presented.

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 (Table 15).

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.

The biomagnification potential of HBCDD has been assessed by comparing measured levels of HBCDD in prey and predators using the monitoring data available in the EU RAR. All available data from monitoring studies show that HBCDD biomagnifies in the marine and aquatic food webs. In addition, many studies suggest an increase in the concentration of HBCDD in biota over time (EU RAR of HBCDD 2007).

Table 15 Measured values of HBCDD in environmental compartments, biota and humans (EU RAR HBCDD, 2007)

Levels in environmental compartments		
Surface water	< 0,02 – 1,5	µg/L
Sediment	< 0,1 – 11 000	µg/kg dry weight
Soil	0,14 – 90	µg/kg dry weight
Sewage sludge	< 0,3 –9 120	µg/kg dry weight
Levels in biota (selection)		
Fish (perch, eel, trout)	< 0,03 – 9.432 (27.705)	µg/kg lipid
Moss (Norway)	< 1,5 – 11 114	µg/kg wet weight
Peregrine falcon eggs (Greenland, Sweden)	< 0,002 – 160 (590)	µg/kg wet weight (lipid)
Crustaceans (mussels, shrimp)	< 0,5 – 329 (17 337)	µg/kg wet weight (lipid)
Marine fish (muscle)	< 0,001 – 49 (1 113)	µg/kg wet weight (lipid)
Marine fish (liver)	< 0,3 – 89	µg/kg wet weight
Marine mammals (dolphin, seal, porpoise)	0,5 – 6.400 (21 345)	µg/kg wet weight (lipid)
Polar bear	5 - 45	µg/kg wet weight
Marine birds	0,5 - 100	µg/kg wet weight
Levels in humans		
Human breast milk (Sweden, Norway, Mexico)	< 0,2 – 5,4	µg/kg lipid

In parentheses: extremely high single value

In addition to the monitoring data presented in the EU RAR further findings of HBCDD in tissues of humans, dolphins, and sharks are reported by Johnson-Restrepo et al. (2008). Concentrations of HBCDD in human adipose tissue obtained in New York City, and in three top-level marine predators, namely, bull shark, Atlantic sharpnose shark, and bottlenose dolphin, all collected from Florida coastal waters between 1991 and 2004.

The highest concentration of HBCDD found in human tissues was 2,41 µg/kg lipid wt. Concentrations of HBCDD in muscle tissues from two shark species and bubbler from dolphins collected from the coastal waters of Florida are reported in Table 16.

The highest concentration of HBCDD was found in muscle tissues from bull shark (413 µg/kg lipid wt).

Table 16 Measured values of HBCDD in biota (Johnson-Restrepo et al. 2008)

Species	No. of samples	Tissue	Location	Year	HBCDD [µg/kg lipid wt]	
Bottlenose dolphin	4	Blubber	West coast of Florida	1991–1996	Mean	2,21
					Range	0,537–6,19
					% Positive	100
	5	Blubber	West coast of Florida	2000–2001	Mean	15,5
					Range	0,460–72,6
					% Positive	100
	6	Blubber	East coast of Florida	2001–2004	Mean	4,02
					Range	0,720–9,11
					% Positive	100
Bull shark	6	Muscle	East coast of Florida	1993–1994	Mean	84,9
					Range	9,15–413
					% Positive	100
	7	Muscle	East coast of Florida	2002–2004	Mean	71,6
					Range	16,6–310
					% Positive	100
Atlantic sharpnose shark	3	Muscle	East coast of Florida	2004	Mean	54,5
					Range	1,83–156
					% Positive	100

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 of HBCDD and sewing of flame retarded textiles.

EEE relevant applications include the use of HBCDD in HIPS. 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 generating handling of these materials will therefore 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

HBCDD may be released to the environment through wastewater and air effluents from manufacture, formulation, industrial use, use and disposal of HBCDD containing products. Since HBCDD is a rather persistent and bioaccumulating substance emitted from both point sources and diffuse sources, it could be expected that the exposure to man via food is an important route of exposure.

The largest amount of HBCDD ingested by man is estimated in the EU RAR to come from 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 EU RAR of HBCDD summarises that human exposure of different populations by multiple exposure routes is possible. These are workers, consumers, and humans exposed to HBCDD via the environment (via food, drinking water and air). Worker and consumer exposure are mainly via the dermal and inhalation routes, whereas exposure via the environment occurs via the oral route.

Although the most important exposure situations probably have been covered, it is recognised in the EU RAR that not all exposed consumers may have been identified since it was not possible to obtain information on all the possible exposure situations for HBCDD in the European Union.

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 well-functioning incinerators the risk of formation of brominated and mixed halogenated dioxins and furans is negligible. In case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators, however, there is a risk of formation of PBDDs and PBDFs.

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

Conclusions of Risk Reduction Strategy Meeting

The 15th Risk Reduction Strategy Meeting (EU Commission 2008a) has drawn the following conclusions within the draft recommendation appendices for HBCDD:

A) HUMAN HEALTH

The conclusion of the assessment of the risks to

WORKERS

is that there is a need for specific measures to limit the risks. This conclusion is reached because of:

- concern for repeated dose toxicity as a consequence of inhalation and dermal exposure arising from producing fine grade HBCDD-powder.

The conclusion of the assessment of the risks to

CONSUMERS

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to

HUMANS EXPOSED VIA THE ENVIRONMENT

is that there is a need for specific measures to limit the risks. This conclusion is reached because of:

- concerns for repeated dose toxicity as a consequence of oral exposure via food arising locally from industrial use of HBCDD in textile backcoating and at one site using HBCDD in XPS.

The conclusion of the assessment of the risks to

HUMAN HEALTH (arising from physico-chemical properties)

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

B) ENVIRONMENT

The conclusion of the assessment of the risks to the

ATMOSPHERE:

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to the

AQUATIC ECOSYSTEM

is that there is a need for specific measures to limit the risks. The conclusion is reached because of:

- concerns for local effects on the aquatic and marine ecosystem as a consequence of exposure arising from formulation of EPS, XPS, and polymer dispersions for textile industry
- concerns for local effects on the aquatic and marine ecosystem as a consequence of exposure arising from industrial use of XPS and HIPS, and from textile backcoating

- concerns for non-compartment specific effects relevant for the aquatic and marine food chains (secondary poisoning) as a consequence of exposure arising from formulation of EPS, XPS, and polymer dispersions for textile industry
- concerns for non-compartment specific effects relevant for the aquatic and marine food chains (secondary poisoning) as a consequence of exposure arising from industrial use of EPS, XPS, and HIPS, and from textile backcoating.

The conclusion of the assessment of the risks to the

TERRESTRIAL ECOSYSTEM

is that there is a need for specific measures to limit the risks. The conclusion is reached because of:

- concerns for local effects on the terrestrial ecosystem as a consequence of exposure arising from industrial use of XPS compound and from textile backcoating.
- concerns for non-compartment specific effects relevant for the food chain (secondary poisoning of terrestrial predators) as a consequence of exposure arising from industrial use of XPS and from textile backcoating.

The conclusion of the assessment of the risks to

MICRO-ORGANISMS IN THE SEWAGE TREATMENT PLANT:

is that there is a need for specific measures to limit the risks. The conclusion is reached because of:

- concerns for effects on sewage treatment plants as a consequence of exposure arising from sites with industrial use of XPS having intermittent releases to waste water and for textile backcoating.

The conclusion of the

PBT/vPvB-ASSESSMENT:

is that there is a need for specific measures to limit the risks. The conclusion is reached because of:

- concerns caused by HBCDD being a PBT-substance

The following strategy for limiting risks has been proposed by the 15th Risk Reduction Strategy Meeting:

WORKERS:

- the legislation for workers' protection currently in force at Community level is generally considered to give an adequate framework to limit the risks of the substance to workers to the extent needed and shall apply.

ENVIRONMENT AND MAN VIA THE ENVIRONMENT:

- Due to the fact that any further developments will be taken by REACH, it has been concluded that it is premature to discuss the possible restrictions part at this stage.
- However, it is recommended that the European Commission should consider the inclusion of HBCDD in the priority list of Annex X to Directive 2000/60/EC[35] during the next review of this Annex. Furthermore, it is recommended to consider developing a proposal for the inclusion of HBCDD in the Stockholm convention on POPs.

3.2.5 Partial conclusion on HBCDD

In the EU RAR (2007) it is concluded that HBCDD overall fulfils the PBT-criteria although the P-criterion is not unequivocally fulfilled. In accordance with REACH, ECHA has published an Annex XV dossier for HBCDD prepared by Sweden with the proposal to identify HBCDD as a PBT substance and thus as SVHC[36].

HBCDD has been detected in environmental compartments and in biota in very remote areas far from potential sources. These findings suggest that HBCDD undergoes long-range atmospheric transport, accumulates in biota and biomagnifies in the marine and aquatic food webs.

The Risk Reduction Strategy Meeting has come to the conclusion that concerning workers, and humans exposed via the environment there is a need for specific measures to limit the risks. The same applies to aquatic and terrestrial ecosystems as well as to microorganisms in the sewage treatment plant. According to the Risk Reduction Strategy Meeting, the legislation for workers' protection currently in force at Community level is generally considered to give an adequate framework to limit the risks of HBCDD to workers to the extent needed. Concerning the risk to the environment and humans via the environment reference is made to the ongoing activities under REACH (see above). Furthermore, it is

---

[35] European Parliament and Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22/12/2000, p. 1.

[36] Following completion of the Annex XV dossier, HBCDD may be included in the candidate list for possible inclusion in Annex XIV. Substances in Annex XIV will be subject to authorisation. Once the candidate list is established, some substances of very high concern will be prioritised. Priority will normally be given to substances with PBT or vPvB properties that have a wide dispersive use or are manufactured or imported in high volumes.

recommended to consider developing a proposal for the inclusion of HBCDD in the Stockholm convention on POPs.

Because of the observed long-range transport of HBCDD to remote areas, the bioaccumulation and even biomagnification in food webs with unpredictable long-term effects immediate action is considered necessary by the authors of the present study to cease further emissions of HBCDD into the environment. Further concerns arise from the possible formation of dioxins and furans under uncontrolled incineration conditions and in countries without advanced emission control technology like many Asian and African countries where a considerable amount of used and obsolete EEE is shipped.

The necessity to limit the risk for the environment and for humans via the environment has also been identified in the EU RAR and in the RRS Meeting. However, although HBCDD is proposed to be identified as SVHC under REACH, it is not sure yet whether HBCDD will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent HBCDD will be regulated under REACH (for more details please refer to Section 6.2.1). Therefore, on basis of the current information it is proposed to regulate HBCDD under the RoHS Directive and to phase it out from EEE. Thus, HBCDD is considered as a potential candidate for an inclusion in RoHS.

3.2.6 References

- EU Commission (2008a): The 15th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Control of Risks of Existing Substances (22/24 April 2008); Subject: Draft Recommendation Appendices for Hexabromocyclododecane (HBCDD); Doc: ES/25e/2007 Rev.2.
- Johnson-Restrepo, B. et al. (2008): Tetrabromobisphenol A (TBBPA) and hexabromocyclododecanes (HBCDs) in tissues of humans, dolphins, and sharks from the United States; Chemosphere 70 (2008) 1935–1944.
- KEMI (2006): Survey and technical assessment of alternatives to TBBPA and HBCDD. Report No. 1/06. https://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_06.pdf.
- KEMI (2007): Strategy for limiting risks – Hexabromocyclododecane (HBCDD), Draft September 2007, inedited.
- Risk Assessment Hexabromocyclododecane. Final Draft October (2007).
- Sweden (2008a): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Proposal for identification of Hexabromocyclododecane as a SVHC.

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

3.3.1 Classification

MCCPs meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC. They are not yet listed on Annex I to Directive 67/548/EEC. However, MCCPs are included in the adopted 30th Adaptation to Technical Progress (ATP) of Directive 67/548/EEC. The proposed classification for MCCPs in relation to human health and environmental effects is as follows:

Human health	R64: May cause harm to breastfed babies. R66: Repeated exposure may cause skin dryness or cracking
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[37], 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

Based on preliminary modelling work, it is assumed that some components of the technical MCCP products could be persistent, bioaccumulative and toxic and consequently meet the PBT criteria (EU Commission 2008b). Uptake via food appears to be important for MCCPs (possibly resulting in higher concentrations in organisms than may be expected based on the BCF alone). The EU RAR concludes that further information is required to clarify the bioaccumulation potential of the components of MCCPs.

SVHC

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

---

[37] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

3.3.2 Use

The current production capacity of MCCPs is 45 000-160 000 tonnes/year with the main use being as secondary plasticizer in PVC. Secondary plasticizers, when used in combination with primary plasticizers, cause an enhancement of the plasticizing effects and so are also known as extenders. Further MCCPs are used as metal working fluids, paints and varnishes, adhesives/sealants, flame retardants, leather fat liquors, carbonless copy paper.

EEE relevant appliances of MCCPs 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. MCCPs with higher degrees of chlorination are more compatible with PVC and have a lower volatility than lower chlorinated analogues. MCCPs with 52% wt. Cl make up around 2/3 of the 51 827 tonnes used for PVC production. The actual amount of MCCPs used in the various PVC applications is not defined in detail. According to industry information it can be assumed that approximately 17% of the total amount of MCCP supplied for PVC applications is used in cable products. Based on this figure, 9 200 tonnes/year of MCCP are used for cable products.

The use of MCCPs in plastics other than PVC can be considered to be primarily as a flame retardant additive. If MCCPs are 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.

3.3.3 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 legislation covers the use of MCCP containing products:

- 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.
- EU RAR in accordance with Council Regulation (EEC) 793/93

3.3.4 Risk assessment

The data and information presented in this chapter derive from the final EU RAR of MCCP, Part I – Environment (2005) and the draft EU RAR of MCCP, Part II – Human Health (February 2008).

For sources other than the EU RAR, respective references are given.

Environment

Exposure

Releases of MCCPs to the environment may occur during their production as well as during the different uses as (secondary) plasticisers in PVC; plasticiser/flame retardant in other plastics, rubber and in sealants/adhesives, as a plasticiser in paints and varnishes and as an extreme pressure additive in metal cutting/working fluids. Emissions are mainly directed to wastewater and to the air.

Although MCCPs are of low vapour pressure at ambient temperatures, the vapour pressure is not so low as to preclude the possibility of volatilisation from plastics and other polymers during their service life. This is particularly true of the MCCPs with lower chlorine contents.

As well as volatilisation and leaching losses of MCCPs from products/articles, MCCPs may also enter into the environment as a result of 'waste' from the products themselves during their useful lifetime and disposal. Such waste could include erosion/particulate losses of polymeric products, paints and sealants as a result of exposure to wind and rain or may occur as a result of their mode of use (e.g. wear on conveyor belts, flooring etc.). Similarly, when products/articles are dismantled or disposed of at the end of their useful life there is again a potential for this type of particulate release. In either case the end result is that polymeric particles containing MCCPs could enter into the environment.

Monitoring

Monitoring studies presented in the EU RAR of MCCPs (2007) report measurements of chlorinated paraffins in environmental compartments, in biota and in human breast milk (Table 17).

Additional monitoring data from Norway show widespread occurrence in the environment (SFT 2007).

Table 17 Measured values of chlorinated paraffins in environmental compartments, biota and humans (EU RAR MCCPs, 2005)

Levels in environmental compartments		
Surface water (UK)[a)]	< 0,62 – 3,75	µg/L
Sediment (UK)	>5	mg/kg wet weight
Levels in biota (selection)		
Mussels [a)]	100 - 12 000	µg/kg
Grey seal (liver and blubber) [a)]	40 - 100	µg/kg
Heron (liver) [a)]	100 - 1 200	µg/kg wet weight
Sheep liver (close to chlorinated paraffin production plant) [a)]	200	µg/kg
Rabbit muscle[b)]	2 900	µg/kg lipid
Moose muscle [b)]	4 400	µg/kg lipid
Fin whale[c)]	144	µg/kg (fat weight basis)
Cow's milk (UK) [c)]	63	µg/kg lipid
Beluga whale (blubber) [c)]	15 800 – 80 000	µg/kg wet weight
Levels in humans		
Human breast milk (UK) [c)]	6,2 - 320	µg/kg lipid

[a)] combined short- and medium-chain chlorinated paraffins (C10-20)
[b)] chlorinated paraffins (unspecified chain length)
[c)] medium-chain chlorinated paraffins (C14-17)

Human health

Occupational exposure

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.

Consumer exposure

MCCPs are not sold directly as consumer products. However, they are found in the following materials to which consumers could be exposed: in fat liquors used in leather processing, as an additive to adhesive and sealants, use in rubber and plastics, as a plasticiser in paints, as an extreme pressure additive in metal working fluids. Although these are largely for industrial or commercial applications, there may be the potential for indirect consumer exposure. In the EU RAR the exposure of consumers from most applications has been considered to be negligible.

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.

Disposal

Since MCCPs are not generally reacted or 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 in total. The vast majority of this amount is likely to be present in PVC articles, as this is the major use of medium-chain chlorinated paraffins. No information is given in the EU RAR on the recycling rate of PVC cables, a use that is relevant for the EEE application.

Of the possible disposal methods, incineration is likely to completely destroy MCCPs, provided that incineration takes place under controlled conditions. However, in case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators, chlorinated paraffins can basically be a source of chlorine then leading to the formation of polychlorinated dioxins and furans. Furthermore 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. However, there is insufficient information available on this issue to make an assessment.

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.

Conclusions of Risk Reduction Strategy Meeting

The 15th Risk Reduction Strategy Meeting (EU Commission 2008b) has drawn the following conclusions within the draft recommendation appendices for MCCPs:

A) HUMAN HEALTH

The conclusion of the assessment of the risks to

WORKERS

is that there is a need for specific measures to limit the risks. This conclusion is reached because of:

- concerns for repeated dose toxicity (kidney effects), carcinogenicity, effects mediated via lactation and for effects at the time of parturition as a consequence of repeated exposure arising from oil-based MWF (metal working fluids) use.

The conclusion of the assessment of the risks to

CONSUMERS AND HUMANS EXPOSED VIA THE ENVIRONMENT

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to

HUMAN HEALTH (arising from physico-chemical properties)

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

B) ENVIRONMENT

The conclusion of the assessment of the risks to the

ATMOSPHERE

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the assessment of the risks to the environment for

AQUATIC ECOSYSTEM AND TERRESTRIAL ECOSYSTEM

is that there is a need for specific measures to limit the risks. This conclusion is reached because of:

- concerns for effects on the aquatic (including sediment) environment as a consequence of exposure arising from the use in the production of PVC, formulation and use of metal cutting/working fluids and use of leather fat liquors. In addition concerns for effects on sediment as a consequence of exposure arising from the use in the production of plastics/rubber and recycling of carbonless copy paper.

- concerns for the terrestrial environment as a consequence of exposure arising from use in the production of PVC, formulation and use of metal cutting/working fluids, use in leather fat liquors, and regional exposure from “waste remaining in the environment”.
- concerns for non compartment specific effects to the environmental spheres mentioned above as a consequence of exposure arising from use in leather fat liquors and specifically for terrestrial food-chain from use in the production of PVC, production of plastics/rubber, and use in metal cutting/working fluids.

The conclusion of the assessment of the risks to

MICRO-ORGANISMS IN THE SEWAGE TREATMENT PLANT

is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusion of the

PBT/vPvB-ASSESSMENT

is that there is a need for further information and/or testing.

This conclusion is reached because uptake via food appears to be important for medium-chain chlorinated paraffins (possibly resulting in higher concentrations in organisms than may be expected based on the BCF alone), and, based on preliminary modelling work, it is also possible that some components of the technical medium-chain chlorinated paraffin products could be persistent, bioaccumulative and toxic and consequently meet the PBT criteria. Further information is therefore required to clarify the bioaccumulation potential of the components of medium chain chlorinated paraffins.

The following strategy for limiting risks has been proposed by the 15th Risk Reduction Strategy Meeting:

For *ENVIRONMENT*

- To consider at Community level marketing and use restrictions in Council Directive 76/769/EC for the use of MCCPs in fat liquors used by the leather industry.

- Competent authorities in the Member States concerned should lay down, in the permits issued under Directive 2008/1/EC of the European Parliament and of the Council[38], conditions, emission limit values or equivalent parameters or technical measures regarding MCCPs in order for the installations concerned to operate according to the best available techniques (hereinafter "BAT") taking into account the technical characteristic of the installations concerned, their geographical location and the local environmental conditions.
- To facilitate permitting and monitoring under Directive 2008/1/EC MCCPs should be included in the ongoing work to develop guidance on ‘Best Available Techniques’.
- To consider the inclusion of MCCPs in the priority list of Annex X to Directive 2000/60/EC[39] during the next review of this Annex.
- It is recommended that for river basins where emissions of MCCPs 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 Directive 2000/60/EC[40].
- Local emissions to the environment of MCCPs should, where necessary, be controlled by national rules to ensure that no risk for the environment is expected.

Due to the lacking measures concerning the use of MCCPs in metalworking fluids and in PVC the Commission proposal could not be finalised.

3.3.5 Partial conclusion on MCCPs

MCCPs have been assigned endocrine disruption Cat. 1 and it is assumed that some components of the technical MCCP products could be persistent, bioaccumulative and toxic and consequently meet the PBT criteria. The Risk Reduction Strategy Meeting sees the need for further information and/or testing to clarify the PBT assessment.

MCCPs, together with other chlorinated paraffins, have been detected in environmental compartments, in biota and in human breast milk at significant levels.

The Risk Reduction Strategy Meeting has come to the conclusion that for the use as metal working fluid there is a need for specific measures to limit the risks for workers. For aquatic

---

[38] OJ L 24, 29.1.2008, p. 8

[39] European Parliament and Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22/12/2000, p. 1.

[40] European Parliament and Council Directive 2000/60/EC of 23 October 2000 establishing a framework for community action in the field of water policy, OJ L 327, 22/12/2000, p.1.

and terrestrial ecosystems there is also a need for specific measures to limit the risks arising from various applications of MCCPs.

According to the new Guidance for the implementation of REACH (ECHA 2008), substances that can be shown both to persist for long periods and to bioaccumulate in biota and which can cause toxic effects after a longer time and over a greater spatial scale give rise to specific concern. Due to their persistence they have the potential to accumulate in parts of the environment. The effects of such accumulation are unpredictable in the long-term and such accumulation is practically difficult to reverse. It is concluded in the Guidance for the implementation of REACH that these properties may lead to an increased uncertainty in the estimation of risk to human health and the environment when applying quantitative risk assessment methodologies as done in the EU RAR for MCCPs. For substances with persistent, bioaccumulating and toxic properties a “safe” concentration in the environment cannot be established using the methods currently available with sufficient reliability for an acceptable risk to be determined in a quantitative way.

Despite of the comprehensive risk assessment presented in the EU RAR there are concerns regarding the findings of MCCPs in biota and breast milk with unknown long-term effects. Further concerns arise from the possible formation of dioxins and furans under uncontrolled incineration conditions and in countries without advanced emission control technology like many Asian and African countries where a considerable amount of used and obsolete EEE is shipped. These aspects have not or only partly be taken into account in the EU RAR of MCCPs. On basis of these potential risks for the environment and human health MCCPs is considered as a potential candidate for an inclusion in RoHS.

3.3.6 References

- 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.
- EU Risk Assessment Report Alkanes, C14-17, chloro (MCCP), Part I – Environment Final Report (2005).
- EU Risk Assessment Report Alkanes, C14-17, chloro (MCCP), Part II – Human Health Draft of February 2008.
- EU Commission (2008b): The 15th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Control of Risks of Existing Substances (23/24 April 2008); Subject: Draft Recommendation Appendices for MCCPs; Doc: ES/12f/2007 Rev. 1.

- 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.
- SFT (2007): Impact assessment of a proposal for prohibition on certain hazardous substances in consumer products; Norwegian Pollution control Authority.
- 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.

3.4 Short-chained chlorinated paraffins (SCCPs)

3.4.1 Classification

SCCPs are included in Annex I to Directive 67/548/EEC with the following classification:

Human health	Xn; Carcinogen Category 3: R40 - Possible risk of irreversible effects. R66[41] - Repeated exposure may cause skin dryness or cracking
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 have been 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

Based on the results of the biodegradation tests SCCPs are considered to be persistent (P) and very persistent (vP). The available BCF data indicate that SCCPs meet both the bioaccumulative (B) and the very bioaccumulative (vB) criteria. In addition, SCCPs have been found to be present in marine top predators.

Moreover, SCCPs are toxic substances. Therefore, SCCPs fulfil the PBT criteria.

---

[41] R66 is added to the classification of SCCPs through the adopted 30th ATP

SVHC

The European Chemicals Agency ECHA has published an Annex XV dossier for SCCPs with a proposal for identification of SCCPs as a SVHC (UK REACH Competent Authority 2008). Within this dossier it is proposed to identify SCCPs as PBT according to REACH Article 57 (d).

3.4.2 Use

In 1994, 13 208 tons SCCPs were used in Western Europe. The main uses of SCCPs have been 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.

3.4.3 Current legislation

- The EU RAR in accordance with Council Regulation (EEC) 793/93 was published in October 1999, updated in 2008[42]. Subsequent marketing and use restrictions for two uses (metal working and fat liquoring of leather) have come into force in the European Union through Directive 2002/45/EC. This Directive also states that all remaining uses of short-chain chlorinated paraffins will be reviewed by the European Commission before 1st January 2003, in cooperation with Member States and the OSPAR Commission, in light of any relevant new scientific data on risks posed by short-chain chlorinated paraffins to health and the environment.
- 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 subject to discussions under the two international instruments governing POP substances, the Stockholm Convention under UNEP (2007) and the UN-ECE Protocol on POPs under the LRTAP[43].
- Annex XV dossier prepared by UK (UK REACH Competent Authority 2008)

---

[42] http://ecb.jrc.it/documents/Existing-Chemicals/RISK_ASSESSMENT/REPORT/sccpreport010.pdf

[43] Convention on Long-Range Transboundary Air Pollution

3.4.4 Risk assessment

Environment

Risk characterisation

The EU RAR in accordance with Council Regulation (EEC) 793/93 was published in October 1999. Subsequent marketing and use restrictions for two uses (metal working and fat liquoring of leather) have come into force in the European Union through Directive 2002/45/EC.

The Rapporteur Member State in the framework of Regulation 793/93, the UK, voluntarily updated the original risk assessment on behalf of the Commission in 2008, reviewing new data on the environmental exposure, fate and effects of SCCPs that had become available since the original risk assessment was completed, and re-assessing the risks from the uses other than those already subject to marketing and use restrictions.

This updated RAR was published in 2008.

In the meantime in accordance with Commission Regulation (EC) 642/2005 [Official Journal of the European Union L 107 28.4.2005], industry conducted a test on the persistence of SCCPs which confirmed that the substance is persistent and therefore with the B and T already assessed, SCCPs are considered PBT substances.

This additional information led to the following conclusion in the updated risk assessment:

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

- It is concluded that the substance meets the criteria for a PBT substance. Biodegradation simulation studies have demonstrated that the mineralisation half-life in both freshwater and marine sediment is >180 days (vP), the experimentally determined BCF in fish is 7 816 l/kg (vB) and the lowest chronic NOEC in aquatic organisms is 0,005 mg/l (T).
- Measurements indicate that the substance is widely distributed in the environment. The trend in levels is unknown, and they could be related to former uses that are now controlled. In addition, a clear risk has not been identified on the basis of these measurements. Nevertheless, the occurrence of short-chain chlorinated paraffins in the Arctic and in marine predators cause a concern. In addition, the substance appears to meet the screening criteria for consideration as a candidate persistent organic pollutant (POP) under international conventions.

In the updated risk assessment, the Rapporteur concluded that risk reduction measures should be applied to the following additional scenarios of uses:

- formulation of backcoatings and application of backcoatings to textiles due to local assessment for surface water;
- conversion and combined conversion/compounding of rubber, formulation and processing of textile backcoatings, and industrial use of paints and coatings due to the assessment of secondary poisoning via the aquatic food chain;
- combined compounding and conversion of rubber, formulation and processing of textile backcoatings, and industrial application of paints/coatings due to marine secondary poisoning assessment.

Monitoring

A significant amount of monitoring data is available for short-chain chlorinated paraffins. These indicate that short-chain chlorinated paraffins are present in a wide range of aquatic organisms, including fish and marine mammals, at locations both close to industrial sources and in more remote areas like the Arctic.

In the Annex XV dossier prepared by the UK (UK REACH Competent Authority 2008) it is concluded that SCCPs have been found to be present in a range of biota in the environment, including marine top predators such as seals and whales. This provides supporting evidence that the substance can be taken up by organisms in the environment.

SCCPs appear to meet the screening criteria for consideration as a candidate persistent organic pollutant (POP) under the Stockholm Convention on Persistent Organic Pollutants and under the 1998 Protocol to the UNCECE Convention on Long-range Transboundary Air Pollution on Persistent Organic Pollutants (UK REACH Competent Authority 2008).

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 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.

Indirect exposure via the environment

According to some monitoring studies, SCCPs have been shown to bioconcentrate in aquatic organisms and have 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.

3.4.5 Partial conclusion on SCCPs

The conclusion of the PBT assessment in the updated version of the EU RAR of SCCPs is that SCCPs are confirmed as meeting the criteria for very persistent (vP), very bioaccumulative (vB) and toxic (T) substances. This implies that SCCPs have the potential to pollute marine (as well as other remote) environments. It should be noted that SCCPs have already been detected in the remote Arctic and in marine biota (including top predators such as seals and whales). The trends in levels are unknown, and they may be due (in part at least) to a local source or uses that take place in other regions, or uses that are now controlled in the EU. It is therefore possible that levels may decrease if the current level of emission does not increase. However, the possibility of long range transport can not be excluded.

In addition, SCCPs appear to meet the screening criteria for consideration as a candidate persistent organic pollutant (POP) under international conventions.

Because of the observed long-range transport of SCCPs to remote areas and the bioaccumulation in marine top predators with unpredictable long-term effects immediate action is considered necessary by the authors of the present study to cease further emissions of SCCPs into the environment. Further concerns arise from the possible formation of dioxins and furans under uncontrolled incineration conditions and in countries without advanced emission control technology like many Asian and African countries where a considerable amount of used and obsolete EEE is shipped.

The necessity to limit the risk to the environment has also been identified in the EU RAR for a variety of applications of SCCPs. However, although SCCPs is proposed to be identified as SVHC under REACH, it is not sure yet whether SCCPs will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent SCCPs will be regulated under REACH (for more details please refer to Section 6.2.1). Therefore, on basis of the current information it is proposed to regulate SCCPs under the RoHS Directive and to phase them out from EEE.

3.4.6 References

- EU Risk Assessment Report Alkanes, C10-13, chloro, (1999).
- EU Risk Assessment Report Alkanes, C10-13, chloro, updated version 2008.
- 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.
- UK REACH Competent Authority (2008): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: Alkanes, C10-13, chloro.

3.5 Specific phthalates: DEHP, BBP and DBP

The following chapter gives general information on phthalates. The Chapters 3.6, 3.7 and 3.8 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.

3.5.1 Classification

Table 18 Phthalates and their hazard classification

Phthalates	CAS Numbers	Classification	Endocrine disruption (according to EDS[44])	PBT and vBvP Classification	SVHC
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	EDS database Cat. 1[45]	Not considered as PBT substance, but border-line 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	Not (yet) discussed by TC C&L	No endocrine disrupting effect	Not considered as PBT substance	No

3.5.2 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. Plasticizers have the function of improving the polymer material's flexibility, workability and distensibility. 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

---

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

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

can result in substantial losses to the environment during the lifetime of products and during their disposal (Andersson 2005; UBA 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. The production volume of DEHP in Western Europe for 1997 was 595 000 tonnes/year (EU RAR DEHP 2008). However, the use of DEHP has decreased significantly during the last years in favour of DINP and DIDP (Andersson 2005; EU RAR DEHP 2008). In 2007, DEHP accounted for approximately 18% of the EU total plasticizer use equating to 173 000 tonnes[46].

Table 19 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 (all uses)	Amount used for PVC / polymers	Amount used for PVC in cables & wires
Bis (2-ethylhexyl) phthalate (DEHP)	595 000 tpa in 1997 173 000 tpa in 2007	462 000 tpa in 1997	80 920 tpa in 1997 29 000 tpa in 2007
Dibutylphthalate (DBP)	18 000 tpa in 1998	13 500 tpa in 1998	not specified[47]
Butyl benzyl phthalate (BBP)	19 500 tpa in 2004 5 000 tpa in 2007[48]	8 000 tpa in 2004	not specified
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

3.5.3 Legislation

The use of some phthalates is restricted in the European Union for use in toys and childcare articles: DEHP, BBP, and DBP shall not be used as substances or as constituents of preparations, at concentrations of greater than 0,1% by mass of the plasticized material, in toys and childcare articles. DINP, DIDP, and DNOP shall not be used as substances or as constituents of preparations, at concentrations of greater than 0,1% by mass of the

---

[46] Private communication by Plastic Europe (2008)

[47] No figures are available concerning the amount of DBP and BBP used EEE; however, stakeholders from the electronic industry confirmed that DBP and BBP are used as plasticizers in their products e.g. in connector wires

[48] Private communication by Plastic Europe (2008)

plasticized material, in toys and childcare articles which can be placed in the mouth by children[49].

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[50].

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) on a 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).

According to REACH Regulation, Annex XV dossiers have been prepared for DEHP (by Sweden), BBP (by Austria) and DBP (by Austria). This means in the future that the substances would potentially be submitted to an authorisation regime for all the uses defended by industry.

3.5.4 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.

---

[49] 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

[50] 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

3.5.5 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).
- Austria (2008a): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: benzyl butyl phthalate.
- Austria (2008b): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: dibutyl phthalate.
- 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), Final Report (2008).
- EU Risk Assessment Report Benzyl butyl phthalate (BBP), Final Report (2007).
- 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).
- Koch, H., Drexler, H., Angerer, J. (2005): Der Weichmacher DINP: Exposition der Allgemeinbevölkerung. Umweltmedizin Forschung Praxis, 10, S.319.
- Official Journal of the European Commission (07.02.2008)
- OSPAR Commission (2005, updated 2006): OSPAR Background Document on Phthalates.
- 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. .
- 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
- Sweden (2008b): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Proposal for identification of DEHA as a SVHC.

- TNO – Netherlands Organisation for Applied Scientific Research (2001): Alternatives for phthalates. TNO-Report STB-01-55, Delft.
- UBA – Umweltbundesamt (1999): Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC. Erich Schmidt Verlag, Berlin.
- UBA – Umweltbundesamt (2007): Phthalate – Die nützlichen Weichmacher mit unerwünschten Eigenschaften. http://www.umweltbundesamt.de/uba-info-presse/hintergrund/weichmacher.pdf.

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

3.6.1 Classification

DEHP is included in Annex I to Directive 67/548/EEC (ATP 28) with the following classification:

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 antiandrogenic 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.[51]

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.

---

[51] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

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

The European Chemicals Agency ECHA has published an Annex XV dossier for DEHP with a proposal for identification of DEHP as a SVHC (Sweden 2008b). Within this dossier it is proposed to identify DEHP as a CMR according to Article 57 (a), (b) and/or (c).

3.6.2 Use

DEHP is the most widely used phthalate. The production volume of DEHP in Western Europe for 1997 was 595 000 tonnes/year (EU RAR DEHP, 2008) decreasing to 173 000 tonnes/year in 2007 (private communication by Plastic Europe, 2008). DEHP is mainly used as a plasticizer (up to 97%) in polymer products, mainly PVC. EEE relevant applications of flexible PVC are insulation for cables and wires (80 920 tonnes/year in 1997; 29 000 tonnes/year in 2007) 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 where phthalates can be used as additives to improve the processability. Another use is as a dielectric fluid in capacitors.

3.6.3 Current legislation

Please refer to Section 3.5.3 above.

- 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).
- EU RAR in accordance with Council Regulation (EEC) 793/93
- Commission Recommendation (2007) on risk reduction measures
- Commission Communication (2008) on the results of the risk evaluation and the risk reduction strategies

- Annex XV dossier prepared by Sweden (2008)

3.6.4 Risk assessment

The data and information presented in this chapter derive in a large part from the EU Risk Assessment Report (RAR) on DEHP (2008)[52]. In addition, the results of the risk evaluation and risk reduction strategies have been published in the Official Journal of the European Commission (7 February 2008).

For sources other than the EU RAR, respective references are given.

Environment

Exposure

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.

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.

Human health

Workers

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

Consumers

There is no information indicating that DEHP alone is available to consumers, however, DEHP is used in several products some of which are available to consumers. Consumers may be exposed to DEHP released from consumer products. Because plasticisers in flexible PVC and other materials are not chemically bound, they may be released from the finished

---

[52] http://ecb.jrc.it/documents/Existing-Chemicals/RISK_ASSESSMENT/REPORT/dehpreport042.pdf

article during its life-time. Exposure can also occur from several sources by different routes in different situations. The exposure intensity is expected not to be linear over the product life-time. New products are expected to produce a higher exposure potential than products in which DEHP has reached a steady-state release from the product matrix to medium.

The following product groups are considered for consumer exposure to DEHP in the EU RAR:

- Toys and child-care articles
- Building materials and home furnishing
- Car interiors
- Clothing (rainwear and clothes of artificial leather), gloves and footwear
- Medical devices
- Food contact materials

Exposure to DEHP by the use of flexible PVC cables in EEE has not been considered in the EU RAR.

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.

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.

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.

No information is given in the EU RAR on the recycling rate of PVC cables, a use that is relevant for the EEE application.

Overall conclusions of the risk assessment (EU RAR DEHP 2008)

Environment

ATMOSPHERE

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

AQUATIC ECOSYSTEM

Conclusion (iii) 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:

- concern for birds consuming mussels exposed to DEHP near sites processing polymers with DEHP or sites producing printing inks, sealants and/or adhesives with DEHP. The scenarios that give concern are generic scenarios based on default emission data. There is no concern for the limited number of sites that have reported measured emission data.

Conclusion (i) There is a need for further information and/or testing.

Further refinement of the assessment may remove some concern. This conclusion is reached because of:

- concern for sediment dwelling organisms as a consequence of exposure to DEHP near sites processing polymers with DEHP or sites producing lacquers, paints, printing inks, sealants and/or adhesives with DEHP. The scenarios that give concern are generic scenarios based on default emission data. There is no concern for the limited number of sites that have reported measured emission data.

Further refinement of the assessment may remove some concern. However implementation of risk management measures to address the risks identified for other environmental spheres will eliminate the need for further information on sediment dwelling organisms.

TERRESTRIAL ECOSYSTEM

Conclusion (iii) 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:

- 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. The scenarios that give concern are generic scenarios based on default emission data. There is no concern for the limited number of sites that have reported measured emission data.

Conclusion (i) There is a need for further information and/or testing.

Further refinement of the assessment may remove some concern. This conclusion is reached because of:

- concern for soil organisms exposed to DEHP near sites processing polymers with DEHP or sites producing printing inks, sealants and/or adhesives with DEHP. The scenarios that give concern are generic scenarios based on default emission data. There is no concern for the limited number of sites that have reported measured emission data.

Further refinement of the assessment may remove some concern. However, implementation of risk management measures to address the risks identified for other environmental spheres will eliminate the need for further information on soil organisms.

Micro-organisms in the sewage treatment plant

Conclusion (ii) There is at present no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

Human Health

WORKERS

Conclusion (iii) 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 testicular effects, fertility, toxicity to kidneys, on repeated exposure and developmental toxicity as a consequence of inhalation and dermal exposure during production, processing and industrial end-use of preparations or materials containing DEHP

CONSUMERS

Conclusion (iii) 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 children with regard to testicular effects, fertility, and toxicity to kidneys, on repeated exposure as a consequence of oral exposure from toys and child-care articles, and multiple routes of exposure.
- concerns for children undergoing long-term blood transfusion and neonates undergoing transfusions with regard to testicular toxicity and fertility, as a consequence of exposure from materials in medical equipment containing DEHP.
- concerns for adults undergoing long-term haemodialysis with regard to repeated dose toxicity to kidney and testis, fertility, and developmental toxicity, as a consequence of exposure from materials in medical equipment containing DEHP.

HUMANS EXPOSED VIA THE ENVIRONMENT

Conclusion (iii) 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 children with regard to testicular effects, fertility, and toxicity to kidneys, on repeated exposure as a consequence of exposure via food locally near sites processing polymers with DEHP, or sites producing sealants and/or adhesives, paints and lacquers or printing inks with DEHP. The scenarios that give concern are generic scenarios based on default emission data. There is no concern for the limited number of sites that have reported measured emission data.
- concerns for children with regard to testicular toxicity, as a consequence of exposure via food grown locally near sites recycling paper or municipal sewage treatment plants. The scenarios that give concern are generic scenarios based on default emission data.

HUMAN HEALTH (risks arising from physico-chemical properties)

Conclusion (ii) There is at present no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion is reached because:

- the risk assessment shows that risks are not expected. Risk reduction measures already being applied are considered sufficient.

Risk reduction measures for the environment (Commission Recommendation 2007)[53]

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).

Strategy for limiting the risks for human health (Commission Communication 2008)[54]

For *WORKERS*

The legislation for workers' protection currently in force at Community level is generally considered to give an adequate framework to limit the risks of the substance to the extent needed and shall apply. Within this framework it is recommended:

- to establish at community level Occupational Exposure Limit values for DEHP according to Council Directive 98/24/EC (3).

For *CONSUMERS*

It is recommended:

- to restrict the use of DEHP in packaging materials for foods (plastic materials in contact with food (Directive 2002/72/EC (4)).

---

[53] 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-ethyl-hexyl)phthalate; Phenol; 5-tert-butyl-2,4,6-trinitro-m-xylene (notified under document number C(2007) 5901); (2008/98/EC); Official Journal of the European Union 7.2.2008

[54] 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

- to consider restricting the use of DEHP in medical devices giving rise to possible exposure of neonates and identified groups of concern following the procedure laid down in Council Directive 93/42/EEC (5) concerning medical devices, assuming the availability of safe alternatives.

3.6.5 Partial conclusion on DEHP

DEHP is classified as toxic to reproduction, Category 2; R60-61. Therefore, it is proposed by the European Chemicals Agency (ECHA) to identify DEHP as a CMR according to Article 57 (a), (b) and/or (c). Monitoring data indicate that large amounts of DEHP are diffusely spread in the environment.

The necessity to limit the risk to aquatic and terrestrial ecosystems as well as to workers, consumers and humans exposed via the environment has been identified in the EU RAR for a variety of applications of DEHP. With regard to consumers it is recommended to restrict the use of DEHP in packaging materials for foods and to consider restricting the use of DEHP in medical devices giving rise to possible exposure of neonates and identified groups of concern. Exposure to DEHP by the use of flexible PVC cables in EEE has not been considered in the EU RAR.

Because DEHP in flexible PVC is not chemically bound, it may be released from the electrical and electronic equipment during its life-time. The routes of exposure will mainly include inhalation and dermal exposure. The contribution of emissions from waste is assumed to be high. Disposed material may either be placed in a landfill or incinerated. No information is given in the EU RAR of DEHP on the recycling rate of PVC cables.

DEHP is proposed to be identified as SVHC under REACH, however, it is not sure yet whether DEHP will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent DEHP will be regulated under REACH (for more details please refer to Section 6.2.1). Therefore, on basis of the current information it is proposed to regulate DEHP under the RoHS Directive and to phase it out from EEE.

3.7 Phthalates, II: Butyl benzyl phthalate (BBP)

3.7.1 Classification

BBP is included in Annex I to Directive 67/548/EEC (ATP 29) with the following classification:

Human health	Reprotoxic Category 2; R61: - May cause harm to the unborn child. Reprotoxic Category 3; R62: - Possible risk of impaired fertility. Symbol: T[55]
Environment	N; R50-53. -Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

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[56].

In the EU-RAR (2007) BBP is considered as a suspected endocrine disruptor. It was concluded that further information is needed concerning reproductive toxicity and endocrine effects in fish. A long term fish study on reproductive and endocrine effects has to be performed. In the OSPAR Convention it is stated that BBP is a potential endocrine substance and BBP is put on the list of substances for priority action.

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

The European Chemicals Agency ECHA has published an Annex XV dossier for BBP containing the proposal for identification of BBP as a SVHC (Austria 2008a). Within this dossier it is proposed to identify BBP as a CMR according to Article 57 (c).

---

[55] 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.

[56] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

3.7.2 Use

According to industry data, an estimated amount of 19 500 tonnes/year BBP was 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 (2007); 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. However, stakeholders from the electronic industry confirmed that BBP is used as plasticizer in their EEE products e.g. in connector wires. BBP is used as an extender for a variety of materials included but not limited to sealants, structural bonding compounds, cyanoacrylate adhesives, temporary lens blocking adhesive and electronic module potting compounds. Some of the end use applications are for temporary adhesives in optical equipment fabrication, fast set adhesives, bonding of structural panels, repair putty for pipe joint, conveyor belts, pump liners etc., encapsulants for laser power supplies, military aircraft component encapsulation and encapsulation of control modules for automotive climate control systems.

3.7.3 Current legislation

- 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).
- EU RAR in accordance with Council Regulation (EEC) 793/93
- Annex XV dossier prepared by Austria (2008)

3.7.4 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 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. A long-term fish study on reproductive and endocrine effects has to be performed.

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 as well as humans exposed via the environment.

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 / Humans exposed via the environment

Consumer exposure is considered for cellophane food packaging, for indoor air and for baby equipment/children toys. EEE applications are not considered in the EU RAR of BBP (2007).

It should be noted that recent epidemiological studies have indicated an association between maternal exposures to BBP as well as to other phthalates and the length of the anogenital distance (AGD) in newborn boys. These data support the hypothesis that prenatal phthalate exposure at environmental levels may affect male reproductive development in humans. However, due to small sample size in the studies, this issue will have to be further investigated, and new studies in the future should be taken into account in the risk assessment of BBP.

3.7.5 Partial conclusion on BBP

BBP is classified as toxic to reproduction, Category 2; R61, toxic to reproduction, Category 3; R62 and very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment; R50/53. Because of its reproduction toxicity, it is proposed by the European Chemicals Agency (ECHA) to identify BBP as a CMR according to REACH Article 57 (c). Furthermore, BBP is considered as a suspected endocrine disruptor. Monitoring data indicate that large amounts of BBP are diffusely spread in the environment.

Because BBP in flexible PVC is not chemically bound, it may be released from electrical and electronic equipment during its life-time. The contribution of emissions from waste is assumed to be high. Disposed material may either be placed in a landfill or incinerated. No information is given in the EU RAR of BBP on the recycling rate of PVC cables.

Although BBP is proposed to be identified as SVHC under REACH, it is not sure yet whether BBP will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent BBP will be regulated under REACH (for more details please refer to Section 6.2.1). Therefore, on basis of the current information it is proposed to regulate BBP under the RoHS Directive and to phase it out from EEE.

3.8 Phthalates, III: Dibutylphthalate (DBP)

3.8.1 Classification

DBP is included in Annex I to Directive 67/548/EEC (ATP 28) with the following classification:

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.

<u>Endocrine disruption</u>

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). [57]

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).

<u>PBT and vPvB evaluation</u>

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”.

---

[57] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

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

The European Chemicals Agency ECHA has published an Annex XV dossier for DBP containing the proposal for identification of DBP as a SVHC (Austria 2008b). Within this dossier it is proposed to identify DBP as a CMR according to Article 57 (c).

3.8.2 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).

DBP seems to be of minor relevance for the production of EEE. However, stakeholders from the electronic industry confirmed that DBP is used as plasticizers for a variety of materials e.g. in connector wires. Further end-use applications of DBP include conformal coatings, head bolt sealants, pipe joint compounds, pressure sensitive adhesives, structural adhesives, wearing compounds, magnet bonding adhesives, model aircraft adhesives, epoxy patch kits, thermocouple controller adhesives, and electronic module encapsulants.

3.8.3 Current legislation

Please refer to Section 3.5.3 above.

- EU RAR in accordance with Council Regulation (EEC) 793/93
- Commission Recommendation (2006) on risk reduction measures
- Commission Communication (2006) on the results of the risk evaluation and the risk reduction strategies
- Annex XV dossier prepared by Austria (2008)

3.8.4 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".

Because of its diverse uses DBP is widespread in the environment and has been identified in air, water and soil. Human exposure via the environment may occur through contact with contaminated air, water, soil or food.

DBP has been identified in human breast milk in concentrations ranging from 10 to 51 µg/kg (EU RAR). Whether the DBP in human breast milk originates from direct or from indirect sources is not clear, but given the diffuse use and the diffuse emissions in the environment, the latter is more likely. The exposure to babies is calculated according to the WHO (EU RAR) and varies between 1.2 and 6.0 µg DBP/kg bw/day.

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

Environment

Conclusion (i) There is need for further information and/or testing.

This conclusion is reached because:

- there is a need for better information to adequately characterise the risks to plants exposed via the atmosphere (the airborne toxicity to plants).

The information requirement is a long-term plant toxicity test.

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

This conclusion applies to effects on the aquatic compartment (including sediment), soil and secondary poisoning.

Human health

WORKERS

Conclusion (iii) 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.

It is possible that in some industrial premises adequate worker protection measures are already being applied.

CONSUMERS

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

Risk reduction measures for the environment (Commission Recommendation 2006)[58]

1. The competent authorities in the Member States concerned should lay down, in the permits issued under Council Directive 96/61/EC, conditions, emission limit values or equivalent parameters or technical measures regarding DBP, in order for the installations concerned to operate according to the best available techniques (hereinafter BAT) by the end of October 2007, taking into account the technical characteristic of the installations concerned, their geographical location and the local environmental conditions.
2. Member States should carefully monitor the implementation of BAT regarding DBP and report any important developments to the Commission in the framework of the exchange of information on BAT.

Strategy for limiting the risks for human health (Commission Communication 2006)[59]

For WORKERS

The legislation for workers' protection currently in force at Community level is generally considered to give an adequate framework to limit the risks of the substance to the extent needed and shall apply.

Within this framework it is recommended

---

[58] COMMISSION RECOMMENDATION of 11 April 2006 on risk reduction measures for the substances: Dibutylphthalate; 3,4-Dichloroaniline; Di-'isodecyl' phthalate; 1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich; Di-'isononyl' phthalate; 1,2-Benzenedicarboxylic acid, di-C8-10-branched alkyl esters, C9-rich; Ethylenediaminetetraacetate; Methyl acetate; Monochloroacetic acid; n-Pentane; Tetrasodium ethylenediaminetetraacetate (Text with EEA relevance) (2006/283/EC); Official Journal of the European Union 13.4.2006

[59] Commission communication on the results of the risk evaluation and the risk reduction strategies for the substances: Dibutylphthalate; 3,4-Dichloroaniline; Di-'isodecyl' phthalate; 1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich; Di-'isononyl' phthalate; 1,2-Benzenedicarboxylic acid, di-C8-10-branched alkyl esters, C9-rich; Ethylenediaminetetraacetate; Methyl acetate; Monochloroacetic acid; n-Pentane; Tetrasodium ethylenediaminetetraacetate (Text with EEA relevance) (2006/283/EC); Official Journal of the European Union 13.4.2006

- To establish at community level occupational exposure limit values for DBP according to Directive 98/24/EC.

For CONSUMERS

- To consider at Community level restrictions in Council Directive 76/769/EEC (Marketing and Use Directive) for the use of DPB in toys and childcare articles due to the classification of DPB at a category 2 substance toxic to reproduction and to prevent the use of DPB as a replacement for other plasticizers for this application. As regards other uses the existing legislative measures for consumer protection, in particular the provisions under Council Directive 76/769/EEC (Marketing and Use) as regards CMR substances, are considered sufficient to address risks identified to consumers.

For the ENVIRONMENT

- To facilitate permitting and monitoring under Council Directive 96/61/EC (Integrated Pollution Prevention and Control) DPB should be included in the ongoing work to develop guidance on Best Available Techniques (BAT).

3.8.5 Partial conclusion on DBP

DBP is classified as toxic to reproduction, Category 2; R61, toxic to reproduction, Category 3; R62 and very toxic to aquatic organisms; R50. Because of its reproduction toxicity, it is proposed by the European Chemicals Agency (ECHA) to identify DBP as a CMR according to REACH Article 57 (c). Furthermore, BBP is considered as a suspected endocrine disruptor. Monitoring data indicate that large amounts of DBP are diffusely spread in the environment. DBP has been identified in human breast milk, thus exposure to babies needs to be considered, too.

Because DBP in flexible PVC is not chemically bound, it may be released from electrical and electronic equipment during its life-time. The contribution of emissions from waste is assumed to be high. Disposed material may either be placed in a landfill or incinerated. No information is given in the EU RAR of DBP on the recycling rate of PVC cables.

Although DBP is proposed to be identified as SVHC under REACH, it is not sure yet whether DBP will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent DBP will be regulated under REACH (for more details please refer to Section 6.2.1). Therefore, on basis of the current information it is proposed to regulate DBP under the RoHS Directive and to phase it out from EEE.

3.9 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. The hazards of DNOP were not evaluated at EU level.

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).

3.10 Nonylphenol[60] and nonylphenol ethoxylates

3.10.1 Classification

Nonylphenol is included in Annex I to Directive 67/548/EEC (ATP 29) with the following classification:

Human health	Repr. Cat. 3; R62-63 - possible risk of impaired fertility - possible risk of harm to the unborn child 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 not included in Annex I to Directive 67/548/EEC.

---

[60] 4-nonylphenol (branched) and nonylphenol

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.[61] 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 ethoxylates should be considered as endocrine disruptors (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 product 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 fulfil the criteria for substances of very high concern as defined by REACH.

3.10.2 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,

---

[61] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

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, 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.

According to information provided by the electronic industry during the stakeholder consultation that was part of the present project (see Section 2.3.1), nonylphenol / nonylphenol ethoxylates are not any longer used in electrical equipment as most of the historic uses have already been restricted in EU by 76/769/EEC (see Section 3.10.3).

One stakeholder, however, claimed that nonylphenol ethoxylates are still used as solubilizer in tin electrolytes for printed wiring boards. In this application nonylphenol ethoxylates are used as process chemicals that have the function to reduce the surface tension of tin electrolytes. As process chemicals nonylphenol ethoxylates are not present in the final product.

The use of nonylphenol ethoxylates as adhesive has been indicated by another stakeholder. Furthermore, nonylphenol / nonylphenol ethoxylates are still used in curing systems for epoxy resins. Some of the end use applications include high temperature resistant module potting, current transformer potting, electrically conductive adhesives and general purpose potting compounds.

3.10.3 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
- EU RAR in accordance with Council Regulation (EEC) 793/93
- Directive 76/769/EEC restricts the use of nonylphenol in the several applications

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 already applied. 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.

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.

The conclusions of the risk assessment as published in the Official Journal of the European Communities (2001/838/EC)[62] are as follows:

I. RISK ASSESSMENT

A. HUMAN HEALTH

The conclusion of the assessment of the risks to

WORKERS, CONSUMERS, HUMANS EXPOSED VIA THE ENVIRONMENT

- is that there is a need for further information and/or testing. This conclusion is reached because there is a need for better information to adequately characterise the risks for human health.

B. ENVIRONMENT

The conclusion of the assessment of the risks to the

ATMOSPHERE

- is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied.

This conclusion is reached because the risk assessment shows that risks related to the environmental spheres mentioned above are not expected. Risk reduction measures already being applied are considered sufficient.

The conclusions of the assessment of the risks to the

AQUATIC ECOSYSTEM and *TERRESTRIAL ECOSYSTEM* are:

1. that there is need for further information and/or testing. This conclusion is reached because of:
    - concerns for effects on the aquatic spheres including sediment.

The information and/or test requirements are further toxicity testing on sediment organisms.

---

[62] COMMISSION RECOMMENDATION of 7 November 2001 on the results of the risk evaluation and the risk reduction strategies for the substances: acrylaldehyde; dimethyl sulphate; nonylphenol phenol, 4.nonyl-, branched; tert-butyl methyl ether (notified under document number C(2001) 3380) (Text with EEA relevance) (2001/838/EC)

However, the implementation of the strategy for limiting risks for the environment will eliminate the need for further information requirements;

and

2. that there is a need for specific measures to limit the risks. This conclusion is reached because of:
   - concerns for effects on local and regional aquatic environmental spheres including sediment as a consequence of exposure arising from nonylphenol production, production of phenolic oximes, phenol/formaldehyde resins, epoxy resins and other plastic stabilisers, nonylphenol ethoxylate production, formulation and use,
   - concerns for effects for terrestrial spheres as a consequence of exposure arising from the production, formulation and uses of nonylphenol ethoxylates in veterinary medicines, captive use by the chemical industry, electrical engineering, industrial and institutional cleaning, in leather processing, metal extraction, in the photographic, pulp and paper, polymer and textile industry, in paint manufacture and in civil and mechanical engineering,
   - concerns for effects on secondary poisoning to fish and earthworm predators as a consequence of exposure arising from nonylphenol ethoxylate production and formulation, and the use of nonylphenol ethoxylates in industrial and institutional cleaning, the electrical engineering industry, the paints, lacquers and varnish industry, civil engineering, leather processing, metal extraction, the pulp, paper and board industry, and in textile processing.

The conclusion of the assessment of the risks for

MICRO-ORGANISMS IN THE SEWAGE TREATMENT PLANT

- is that there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied.

This conclusion is reached because the risk assessment shows that risks related to the environmental spheres mentioned above are not expected. Risk reduction measures already being applied are considered sufficient.

II. STRATEGY FOR LIMITING RISKS

for the *ENVIRONMENT*:

Marketing and use restrictions should be considered at Community level to protect the environment from the use of nonylphenol/nonylphenol ethoxylates (NP/NPEs) in particular in:

- 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.

3.10.5 Partial conclusion on nonylphenol and nonylphenol ethoxylates

Marketing and use of nonylphenol has already been restricted for a number of applications by Directive 76/769/EEC. The specific use of nonylphenol and nonylphenol ethoxylates in EEE has neither been considered in the EU RAR nor in Directive 76/769/EEC. Because of the identified risks for environmental compartments arising from the production, formulation and uses of nonylphenol and nonylphenol ethoxylates, a restriction of use in electrical and electronic equipment of these substances is recommended by the authors of this study.

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 Classification

Beryllium is included in Annex I to Directive 67/548/EEC with the following classification:

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 fulfils the criteria for a substance of very high concern as defined by REACH because it is classified as carcinogenic category 2.

3.11.2 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 moulds;
- Fire extinguisher sprinkler heads;
- Aircraft landing gear bushings;
- Undersea repeater housings;
- Oilfield drill collars & friction bushings.

Beryllium oxide ceramic applications

(Containing 20% to 100% beryllium)

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).

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

3.11.3 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.

3.11.4 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 high for EEE workers (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) set the *Permissible Exposure Limit* (PEL) at 2 µg/m³ per working day. The U.S. National Institute for Occupational Safety and Health (NIOSH) recommends 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 long-term inhalative exposure of the general public (not for occupational exposure), Schuhmacher-Wolz and Schneider (2004) proposed a reference concentration of 0,01µg/m³, referring to the study of Kreiss et al. (1996).

As mentioned above, 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 do not reject any dust or fumes when they are 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, mainly used in high-end products where it remains environmentally inert during its useful lifecycle stage.

Risk characterisation

There is no EU RAR available for beryllium. A potential occupational risk is associated with the manufacturing of beryllium-containing products, and with 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).

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, elevated 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 2.6).

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.

3.11.5 Partial conclusion on beryllium and beryllium oxide

Beryllium is classified as carcinogenic category 2; R49 with possible carcinogenic effects by inhalation: 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) which is why many countries have adopted occupational exposure limits. Furthermore, it is toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment.

Beryllium metal including composites and beryllium oxide ceramics are rarely used in consumer electrical and electronic equipment. The main use is in high-end products with long life-cycles. Beryllium metal as a hard and fully dense metal and beryllium oxide as a hard and fully dense ceramic do not reject any dust or fumes when they are supplied and used in EEE applications. Due to the relatively high costs of beryllium metal and beryllium oxide industry aims at dismantling and recycling beryllium from waste EEE.

In contrast, beryllium-containing alloys are used in consumer products with cellular phones being the application containing the highest beryllium content.

An EU RAR is not available for beryllium, however, existing publications examining the impacts of airborne metal exposure among workers due to shredding, roasting, milling and assaying of recycled cellular phones show that the airborne beryllium exposures are below the *Permissible Exposure Limit* (PEL).

The available data is not considered to be sufficient by the authors of this study to justify a restriction of beryllium from EEE at the current stage. The presence of beryllium containing parts in EEE above a certain concentration level should, however, be labelled in order to ensure that these parts are dismantled and recycled adequately.

3.11.6 References

- Andersson, E. (2005), Hazardous substances in electrical and electronic equipment (EEE), Project report, Göteborg University, Swedish Chemicals Inspectorate (KemI).
- Bruce, R. M., and Odin, M., (2001), Beryllium and beryllium compounds, United Nations Environment Programme, the International Labour Organization, and the World Health Organization, Geneva.
- C4E (2002), Guidance Document on the Application of Substances under Special Attention in Electric & Electronic – Products, Published in co-operation by CEFIC, EACEM, EECA, EICTA and EUROMETAUX, Version 2.2.
- EPA (2008), Technical factsheet: Beryllium, Retrieved April 04, 2008, from http://www.epa.gov/OGWDW/dwh/t-ioc/berylliu.html.
- 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, Final report, Ottawa.
- Greenpeace International (2005), Recycling of Electronic Wastes in China & India: Workplaces & Environmental Contamination, report.
- Kent, M.S., Corbett, M.L., and Glavin, M., (2007), Characterization and Analysis of Airborne Metal Exposures among Workers Recycling Cellular Phones, Brush Wellman Inc., Elmore, OH.
- Knudson, T., (2008), A qualitative overview of the use of beryllium, beryllium-containing alloys and beryllium oxide ceramic in electrical and electronic equipment (EEE), Brush Wellman Inc., Elmore, OH.
- National Institute of Environmental Health Sciences (2005), 11th ed. Report on Carcinogens, Beryllium and beryllium compounds, Retrieved April 10th, 2008 from http://ntp.niehs.nih.gov/ntp/roc/eleventh/profiles/s022bery.pdf.
- Paustenbach, D. J., Madl, A. K., and Greene, J. F., (2001), Identifying an Appropriate Occupational Exposure Limit (OEL) for Beryllium: Data Gaps and Current Research Initiatives, Applied Occupational and Environmental Hygiene, Vol. 16, Nr. 5, May 2001, pp. 527-538(12).
- Schuhmacher-Wolz, U., and Schneider, K., (2004), Addendum Beryllium und Verbindungen, in Eikmann, T. (2007), Gefährdungsabschätzung von Umweltschadstoffen, Erich Schmidt Verlag.

3.12 Antimony trioxide

3.12.1 Classification

Antimony trioxide is included in Annex I to Directive 67/548/EEC with the following classification:

Human health	Carc. Cat. 3; R40 - limited evidence of carcinogenic effect

Endocrine disruption

There is no categorisation according to the EDS database of the EU.

PBT and vPvB evaluation

According to the EU RAR there is currently no agreed approach to perform a PBT-assessment of a metal; therefore a PBT-assessment has not been performed for antimony trioxide.

SVHC

Antimony trioxide does not fulfil the criteria for a substance of very high concern as defined by REACH.

3.12.2 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 9 200 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 exist 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 resulting most probably in a decrease of antimony trioxide in EEE.

Table 20 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 application**
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 preparations:
C ≥ 25%: Xn, N; R20/22-51/53
2,5 % ≤ C < 25%: Xn; R20/22-52/53
0,25 % ≤ C < 2,5%: Xn; R20/22

3.12.3 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/m³ antimony trioxide on average have been established in several EU countries
- Draft EU RAR in accordance with Council Regulation (EEC) 793/93.

3.12.4 Risk assessment

The data and information presented in this chapter derive from the draft EU RAR of diantimony trioxide, environmental part (January 2008).

The human health part 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).

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 and 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 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.

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.

<u>Monitoring</u>

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.

Risk characterisation

The following conclusions to the risk assessment for environmental compartments have been drawn in the draft EU RAR for diantimony trioxide (January 2008).

→ *Conclusions to the risk assessment for SURFACE WATER:*

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all scenarios.

→ *Conclusions to the risk assessment for the SEDIMENT COMPARTMENT:*

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

This conclusion applies to the generic scenarios for formulation and application of flame-retardant textile back-coating and to one production site (site P1).

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all other scenarios, including nineteen sites using diantimony trioxide in textile applications and three production sites, that all report releases.

→ *Conclusions to the risk assessment for WASTE WATER TREATMENT PLANTS:*

Conclusion (ii) At presents, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all scenarios.

→ *Conclusions to the risk assessment for the TERRESTRIAL COMPARTMENT:*

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all scenarios.

→ *Conclusions to the risk assessment for the ATMOSPHERE:*

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion applies to all scenarios.

→ *Conclusions to the risk assessment for SECONDARY POISONING:*

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion applies to all scenarios.

→ *Conclusions to the risk assessment for MARINE SURFACE WATER:*

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

This conclusion applies to formulation of flame-retardant back-coating. There is concern only for the generic scenario using default emission data, none of the sites reporting emission data are known to be located by the sea.

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all other scenarios.

→ *Conclusions to the risk assessment for the MARINE SEDIMENT COMPARTMENT:*

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

This conclusion applies to formulation and application of flame-retardant back-coating. There is concern only for the generic scenario using default emission data, none of the sites reporting emission data are known to be located by the sea.

Conclusion (ii) At present, there is no need for further information and/or testing and no need for risk reduction measures beyond those that are already being applied.

This conclusion applies to all other scenarios.

→ *Conclusions to the risk assessment for MARINE SECONDARY POISONING:*

Conclusion (ii) There is at present no need for further information and/or testing and no need for risk reduction measures beyond those which are being applied already.

This conclusion applies to all scenarios.

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

Exposure of consumers to antimony 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 shows limited risk taking the risk reduction measures already being applied into account. There is a concern for pulmonary toxicity, carcinogenicity 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.

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 concentrations in the feed stream to waste incinerators and in 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-retarded plastics. The use of antimony in the production of flame retardants is estimated to be more than half of all applications. The antimony detected 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 that in the EU about one fourth of the municipal solid waste is incinerated and the remaining part disposed of to a landfill. 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.

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.

3.12.5 Partial conclusion on antimony trioxide

Antimony trioxide is classified as carcinogenic category 3; R40 with limited evidence of carcinogenic effects. A preliminary draft EU RAR for the environmental part has been available during the preparation of the present study, whereas the human health part has still been under discussion in the Competent Group of Member State experts. Due to limited data available on human health and the not yet consolidated data on environmental issues, it is not considered possible by the authors of this study to give a justified recommendation on an inclusion of antimony trioxide in the RoHS Directive.

3.12.6 References

- Crusack, P.A., Herr, M.S. & Monk, A.W. (1997): Zinc hydroxystannate as an alternative synergist to antimony trioxide in polyester resins containing halogenated flame retardants, Polymer Degradation and Stability, Vol. 10, 1-2, pp. 229-237.
- 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 Classification

Bisphenol-A is included in Annex I to Directive 67/548/EEC with the following classification:

Human health	Repr. Cat. 3; R62 - Possible risk of impaired fertility Xi: R37-41; - Irritating to respiratory system - Risk of serious damage to eyes R43: - May cause sensitisation by skin contact R52[63]: - Harmful to aquatic organisms

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[64].

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.

---

[63] R52 is added to the classification of bisphenol-A through the adopted 30th ATP.

[64] http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

SVHC

Bisphenol-A fulfils the criteria for 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).

3.13.2 Use

Bisphenol-A is a chemical intermediate mainly used for the production of polycarbonate and epoxy resins as well as for the production of flexible PVC. It is converted into these plastics by chemical reaction. Thus, only residual amounts of bisphenol-A are present in the final products.

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 electrical / 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 electrical / 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 1 800 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 plasticizers 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 plasticizers 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 TBBP-A a possible formation of bisphenol-A from a breakdown of TBBP-A should be considered. TBBP-A is no longer produced in the EU and, therefore, a risk assessment of bisphenol-A in the manufacture of TBBP-A 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.

3.13.3 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.
- A risk assessment for Bisphenol-A produced in accordance with Council Regulation (EEC) 793/93[65] was published in 2003, with an addendum published in 2008[66].

---

[65] O.J. No. L 084, 05/04/1993 p. 0001 - 0075

3.13.4 Risk assessment

Environment

Exposure

During production of bisphenol-A emissions are released 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 were found at 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 3.13.3). 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 plasticizers used for PVC processing, the preparation of additive packages for PVC production and the use as a plasticizer in PVC processing generate losses to the wastewater during raw material handling, compounding and conversion. 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

---

[66] http://ecb.jrc.it/documents/Existing-Chemicals/RISK_ASSESSMENT/ADDENDUM/bisphenola_add_325.pdf

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

TBBP-A 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.

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 (PEC/PNEC) 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 $PNEC_{water}$ and $PNEC_{marine\ water}$ 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 TBBP-A 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 0,13 µg/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 not 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 is retained 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 of 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 as well as for the manufacture of epoxy resins it is needed to limit the risk 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.

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 TBBP-A, 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.

3.13.5 Partial conclusion on bisphenol-A

Bisphenol-A is a chemical intermediate mainly used for the production of polycarbonate and epoxy resins as well as for the production of flexible PVC. It is converted into these plastics by chemical reaction with only residual amounts of bisphenol-A being present in the final products. Exposure of consumers to bisphenol-A during the use of electrical and electronic equipment is hence considered to be low. There is only a limited amount of data on levels of bisphenol-A in biota cited in the EU RAR.

Overall, on basis of the available data it is concluded that the use of bisphenol-A in EEE does not pose a high risk to human health and to the environment. Therefore, bisphenol-A is not proposed to be included in the RoHS Directive at the current state of knowledge.

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), updated in 2008 [67].
- 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.

---

[67] http://ecb.jrc.it/documents/Existing-Chemicals/RISK_ASSESSMENT/ADDENDUM/bisphenola_add_325.pdf

3.14 Dinickel trioxide

According to information provided by the electronic industry, the use of dinickel trioxide in electrical and electronic equipment is restricted to the production of ceramics i.e. ferrites (NiZnFe compounds) with a nickel content of 11 to 22%.

Taking into account the high temperature production process of ferrites (> 1 000°C) and the thermal instability of dinickel trioxide (decomposition temperature of 600°C), it is highly unlikely that dinickel trioxide is present in the final product at all or at least above trace levels. A second aspect that needs to be taken into account is the reduced (bio-) availability of substances included in inert or massive matrices like glass or ceramics.

Due to the fact that dinickel trioxide is not present in its original chemical form in the final product, it is not further considered in the present study.

3.15 Diarsenic trioxide; arsenic trioxide

According to information provided by the electronic industry, the application of diarsenic trioxide/arsenic trioxide in electrical and electronic equipment is restricted to its use as fining agent in certain special glasses and glass ceramics. Due to the mineralogical melting process, diarsenic trioxide/arsenic trioxide is firmly incorporated in the glass-matrix and is therefore no longer present in its original chemical form. The (bio-) availability of substances included in inert or massive matrices like glass or ceramics is significantly reduced under normal conditions of use. Other uses of diarsenic trioxide/arsenic trioxide e.g. in copper foils in printed circuit boards have been denoted during the stakeholder consultation, but could not be confirmed.

Due to the fact that the application of diarsenic trioxide/arsenic trioxide seems to be restricted to glasses and glass ceramics where it is not present in its original chemical form, it is not further considered in the present study.

3.16 Organobromine and organochlorine compounds

A wide variety of organobromine and organochlorine compounds is used in electrical and electronic equipment, mainly as flame retardants and chlorinated polymers. An overview on relevant examples for this group of substances is given in Table 21. This list, however, is not exhaustive.

Table 21 Examples for organochlorine and organobromine compounds: brominated flame retardants and brominated / chlorinated polymers.

Brominated Flame Retardant	CAS Number
3,5,3’,5’-Tetrabromo-bisphenol A (TBBP-A)	79-94-7
Hexabromocyclododecane	25637-99-4
Poly(2,6-dibromo-phenylene oxide)	69882-11-7
Tetra-decabromo-diphenoxy-benzene	58965-66-5
1,2-Bis(2,4,6-tribromo-phenoxy) ethane	37853-59-1
TBBA, unspecified	30496-13-0
TBBA-epichlorhydrin oligomer	40039-93-8
TBBA-TBBA-diglycidyl-ether oligomer	70682-74-5
TBBA carbonate oligomer	28906-13-0
TBBA carbonate oligomer, phenoxy end capped	94334-64-2
TBBA carbonate oligomer, 2,4,6-tribromo-phenol terminated	71342-77-3
TBBA-bisphenol A-phosgene polymer	32844-27-2
Brominated epoxy resin end-capped with tribromophenol	139638-58-7
Brominated epoxy resin end-capped with tribromophenol	135229-48-0
TBBA-(2,3-dibromo-propyl-ether)	21850-44-2
TBBA bis-(2-hydroxy-ethyl-ether)	4162-45-2
TBBA-bis-(allyl-ether)	25327-89-3
TBBA-dimethyl-ether	37853-61-5
Tetrabromo-bisphenol S	39635-79-5
TBBS-bis-(2,3-dibromo-propyl-ether)	42757-55-1
2,4-Dibromo-phenol	615-58-7
2,4,6-tribromo-phenol	118-79-6
Pentabromo-phenol	608-71-9
2,4,6-Tribromo-phenyl-allyl-ether	3278-89-5
Tribromo-phenyl-allyl-ether, unspecified	26762-91-4
Bis(methyl)tetrabromo-phtalate	55481-60-2
Bis(2-ethylhexyl)tetrabromo-phtalate	26040-51-7
2-Hydroxy-propyl-2-(2-hydroxy-ethoxy)-ethyl-TBP	20566-35-2
TBPA, glycol-and propylene-oxide esters	75790-69-1
N,N’-Ethylene –bis-(tetrabromo-phthalimide)	32588-76-4
Ethylene-bis(5,6-dibromo-norbornane-2,3-dicarboximide)	52907-07-0
2,3-Dibromo-2-butene-1,4-diol	3234-02-4
Dibromo-neopentyl-glycol	3296-90-0
Dibromo-propanol	96-13-9
Tribromo-neopentyl-alcohol	36483-57-5
Poly tribromo-styrene	57137-10-7
Tribromo-styrene	61368-34-1

Brominated / chlorinated polymers	
Polyvinylchloride	9002-86-2
Polyvinylidenechloride	-
Ethylene-Chlorotrifluoroethylene copolymers	-
Polychloroprene	-

Brominated and chlorinated organic substances in electrical and electronic compounds may form polybrominated and polychlorinated dioxins and furans (PBDD/F, PCDD/F) in case of uncontrolled fires (accidental fire) and at co-combustion at lower temperatures or not well functioning incinerators (Brian et al. 2007; Li et al. 2007; Leung et al. 2007). Prevalence of copper in WEEE has a catalytic effect on formation of PBDD/F and PCDD/F. Several European directives limit the level of specific brominated and chlorinated compounds in marketable products (Schlummer et al. 2007). This risk of formation of dioxins and furans applies in general to all organobromine and organochlorine compounds like brominated flame retardants, hydrochlorofluorocarbons, chlorinated paraffins, polyvinylchloride (PVC), etc.

Due to the high diversity in material composition, their content of brominated and chlorinated materials and the combustion conditions, the exact amount of hazardous combustion products can vary widely. (Schlummer et al 2007; Weber and Kuch 2003; Söderström et al. 2002; Detter et al. 2001; Vehlow et al. 2000). Increase of bromine can lead to a shift from chlorinated dioxins and furans to brominated compounds (Lemieux et al. 2002).

Organobromine and organochlorine compounds contained in electrical and electronic equipment are ubiquitously distributed around the globe. Recent studies indicate that still high levels of polybrominated dioxins and furans are found in European WEEE, even after an effective phase-out of polybrominated biphenyls (PBB) (in single housings of TV sets and monitor housings as well as in mixed WEEE fractions) (Schlummer et al. 2007).

Organobromine and organochlorine compounds in WEEE require environmentally sound disposal technologies to ensure a complete thermal degradation of the dioxin/furan precursor substances. Additionally, an effective flue gas cleaning is necessary. It has been shown that under these strictly controlled incineration conditions in a test-incinerator co-combustion of different types of electrical and electronic waste plastics, containing organobromine and organochlorine compounds, with pre-treated municipal solid waste does not lead to significant alterations in the level of PBDD/F (Vehlow et al 2000). In a comparative Life Cycle Analysis including different recovery technologies the recovery of PVC has been assessed as uncritical if it is performed under controlled conditions (PE Europe et al. 2004).

As discussed in Chapter 2.6, there is strong evidence that a 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 of 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 and release 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. For an intensive electronic waste recycling site in China with open burning it has been shown that the body burdens of people from these sites have significantly higher PCDD/PCF levels (human milk, placenta, hair) than those from reference sites. The estimated daily intake of PCDD/PCDFs for breast-fed infants has been found to be two times higher than for reference sites and to exceed the WHO tolerable daily intake 11 to 25 times (Chan et al. 2007). Similar results have been described by Li et al. (Li et al. 2007; Li et al. 2008). 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. The uncontrolled processing of EEE containing organobromine and organochlorine compound is described as one of the major contributors of PBDEs and PDDD/Fs to the terrestrial environment at electronic waste recycling sites (Leung et al. 2007). Comparable results have been found for e-waste recycling sites in other Asian countries such as India, Vietnam and Cambodia (Takahashi et al. 2006).

Highly elevated concentrations of a range of persistent organic pollutants have been found by Wong and colleagues for an intensive electronic recycling site in Guiyu, China, caused by incomplete combustion of WEEE (e.g. plastic chips, wire insulations, PVC materials and metal scraps). Severe pollution has been detected regarding PCDD/Fs, PAHs and PCBs (Wong et al. 2007).

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 a large number of applications.

In the framework of this study it has not been possible to make a full evaluation of all brominated and chlorinated organic compounds. Priority has been given to the following brominated and chlorinated compounds for which it is known that they are used in high amounts in electrical and electronic compounds:

- TBBP-A (see Chapter 3.1);
- HBCDD (see Chapter 3.2);
- Polyvinylchloride (see Chapter 3.17).

Furthermore, medium and short-chained chlorinated paraffins belong to the group of organobromine and organochlorine compounds and are characterised in Chapter 3.3 and 3.4 of this report.

It should be the task of further research to evaluate the use and possible substitutes for other brominated and chlorinated organic compounds which are used in EEE.

It has been discussed whether not only organobromine and organochlorine compounds, but rather all chlorinated and brominated compounds (inorganic as well as organic) should be restricted. The main argument has been that it would not be possible to enforce restrictions on specific organobromine and organochlorine compounds due to the lack of substance-specific and expensive analytical test methods (which have been developed so far only for a limited number of halogenated compounds). Additionally, reactive forms of e.g. brominated flame retardants cannot be detected since their chemical structures change when they are reacted with the base polymer.

Test methods for detecting total bromine and total chlorine content are available; the most prominent one is x-ray fluorescence spectroscopy (XRF). It is much less expensive than test methods which are used to detect specific halogenated organic compounds such as polybrominated Biphenyls or halogenated dioxins and furans.

For a number of commodities resp. material types, bromine- and chlorine-free alternatives have already been developed (see also Chapter 4).

An extension of the recommendation given above (to the exclusion of all brominated and chlorinated compounds) seems to have advantages for the enforcement from an analytical point of view. It should be analysed more in detail whether this would be technically feasible for EEE and whether certain materials should be excluded (e.g. glasses, ceramics, etc.).

3.16.1 References

- Blomqvist, P; Rosell, L; and Simonson, M, (2004): Emissions from Fires Part I: Fire Retarded and Non-Fire Retarded TV-Sets, Fire Technology, 40, 39-58.
- Brian K. Gullett; William P. Linak; Touati, A; J. Wasson, S; Gatica, S; J. King, C, (2007): Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations, J Mater Cycles Waste Manag. 9:69-79.
- Detter, F, T,(2001): Bromorganische Flammschutzmittel – Analytische Anforderungen und thermische Bildung von polybromierten Dibenzo-*p*-dioxinen und Dibenzofuranen, Dissertation von der Gemeinsamen Naturwissenschaftlichen Fakultät der Technischen Universität Carolo-Wilhelmina zu Braunschweig.

- Hamm, S; Schulte, J; Strikkeling M and Maulshagen, A (1999): Determination of polybrominated Diphenylethers (PBDEs) and eight polybrominated Dibenzodioxin (PBDD) and Dibenzofuran (PBDF) isomers in a HIPS/SB2O3/DecaBDE plastic before and after recycling, 19th International Symposium Dioxins99.
- Janet, K, Y, Chan; Xing, G, H; Xu, Y; Liang, Y; Chen, L, X; Wu, S, C; Wong, Chirs, K, C; Leung, Cliement, K, M and Wong, M, H, (2007): Body Loadings and Health Risk Assessment of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans at an Intensive Electronic Waste Recycling Site in China, Environmental Science & Technology / Vol. 41, NO, 22, 2007
- Kuch, B; Weber, R, (2003): Relevance of BFRs and thermal conditions on the formation pathways of brominated and brominated–chlorinated dibenzodioxins and dibenzofurans, Environment International 29, 699-710.
- Lemieux, P, M; Stewart, E, S; Ryan, J, V, (2002): Polit-scale studies on the effect of bromine addition on the emissions of chlorinated organic combustion by-products, Waste Management 22, 381-389
- Leung, A, O, W; Luksemburg, W, J; Wong, A, S and Wong, M, H, (2007): Spatial Distribution of Polybrominated Diphenyl Ethers and Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China. Environ. Sci. Technol. 2007, 41, 2730-2737.
- Li, H; Feng, J; Sheng, G; Lü, S; Fu, J; Peng, P and Man, R, (2008): The PCDD/F and PBDD/F pollution in the ambient atmosphere of Shanghai, China, Chemosphere 70, 576-583.
- Li, H; Yu, L; Sheng, G; FU, J and Peng, P, (2007): Serve PCDD/F and PBDD/F Pollution in Air around an Electronic Waste Dismantling Area in China, Environ. Sci. Technol. 2007, 41, 5641-5646.
- Olsman, H; Engwall, M; Kammann, U; Klempt, M; Otte, J; von Bavel, B and Hollert, H, (2007): Relative Differences in Aryl Hydrocarbon receptor-mediated response for 18 polybrominated and mixed halogenated Dibenzo-*p*-dioxins and – furans in cell lines form four different species, Environmental Toxicology and Chemistry, Vol. 26, No. 11, pp. 2448-2454, 2007.
- PE Europe GmbH et al. (2004): Life cycle assessment of PVC and of principal competing materials; Commissioned by the European Commission, July 2004.
- Schlummer, M; Gruber, L; Mäurer, A; Wolz, G; van Eldik, R (2007): Characterisation of polymer fractions from waste electrical and electronic equipment (WEEE) and implications for waste management, Chemosphere 67 1866-1876.
- Söderström, G and Marklund, S, (2002): PBCDD and PBCDF from Incineration of Waste-Containing Brominated Flame Retardants, Environ. Sci. Technol. 2002, 36, 1959-1964.

- Söderström, G and Marklund, S, (2004): Formation of PBCDD and PBCDF during Flue Gas Cooling, Environ. Sci. Technol. 2004, 38, 825-830.
- Takahashi, S; Kunisue, T; Isobe, T; Noda, S; Subramanian, A; Kajiwara, N; Tana, TS; Viet, PH; Miyazaki, T; Sakai, S; Tanabe, S, (2006): Polybrominated diphenyl ethers and dioxin-related compounds detected in soil samples form waste dumping sites in Asian developing countries, Organohalogen Compounds Vol. 68 (2006).
- Van den Berg, M; Birnbaum, L, S; Denison, M; De Vito, M; Farland, W; Feeley, M; Fiedler, H; Hakansson, H; Hanberg, A; Hauws, L; Rose, M; Safe, S; Schrenk, D; Tohyama, C; Tritscher, A; Tuomisto, J; Tyskling, M; Walker, N; and Peterson, R, E, (2006): The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds, Advance Access Publication July 7, 2006.
- Vehlow, J; Bergfeldt, B; Jay, K; Seifert, H; Wanke, T; Mark, F, E, (2000): Thermal Treatment of E+E Waste Plastics, Waste Management & Research 18, 131-140.
- Wang, L, C; Tsai, C, H; Chang-chien, G and Hung, C, H, (2008): Characterization of Polybrominated Dibenzo-*p*-dioxins and Dibenzofurans in Different Atmospheric Environments, Environ. Sci. Technol. 2008, 42, 75-80.
- Wolf, M; Ernst, T; Müller, B; Popp, R; Van Eldik, R: Bewertung und Optimierung von Verfahren zum Recycling flammgeschützter Kunststoffe aus der Elektrotechnik, BayFORREST- Forschungsvorhaben F116.
- Wong, M, H; Wu, S, C; Deng, W, J; Yu, X, Z; Luo, Q; Leung, A, O, W; Wong, C, S, C; Luksembur, W, J; Wong, A, S, (2007): Export of toxic chemicals – A review of the case of uncontrolled electronic- waste recycling, Environmental Pollution 149, 131-140.

3.17 Polyvinyl chloride (PVC) and other chlorine containing plastics

Chlorine containing plastics, and in particular PVC, involve risks associated with their production, processing and especially with their disposal and incineration. The crucial potential for danger discussed here are the emissions of substances such as organic chlorine compounds and the associated emissions of dioxins and furans especially when PVC is disposed and incinerated.

3.17.1 Classification

Though pure PVC resin is not classified according to Directive 67/548/EEC, the main substances involved in producing PVC polymer are classified as dangerous, namely:

- Vinyl chloride monomer (VCM): F+; R12; Carc. Cat. 1; R45
- Ethylene Dichloride: F; R12; Carc. Cat. 3; R40; Xn; R20

PVC polymer is not used as pure resin in EEE applications, but mainly in form of flexible PVC material that contains various additives. Many of the additives, e.g. plasticizers such as the phthalate DEHP (cf. Section 3.6) or flame retardants such as MCCPs (cf. Section 3.3), are classified as dangerous and are included in Annex I to Directive 67/548/EEC. The plasticizers content varies between 15-60% with typical ranges for most flexible applications around 35-40%. Thus, the PVC material that is used in EEE applications contains significant amounts of hazardous substances classified as dangerous in accordance with Directive 67/548/EEC.

3.17.2 Use

Plastics have gained in importance in EEE appliances and account for 20% by weight of total EEE (BSEF, 2008). PVC is one of the major plastics used in EEE. It is mainly used as insulation and sheathing in wires and cables as well as in telecommunication, for cable management systems and business machine housings. In Western Europe, 5.5 Mio tonnes PVC were produced in 1998 and the production volume grew by 2% every year. EEE appliances add up to 7% of total PVC uses in Europe (resulting in approximately 385,000 tonnes/year on basis of the figures for 1998) and last on average 21 years (EC, 2000).

3.17.3 Current legislation

- Green Paper of 26 July 2000 established by the European Commission lists a range of measures on additives and waste management of PVC.
- Protection of the health of workers exposed to vinyl chloride monomer (VCM), according to Council Directive 78/610/EEC (EC, 2000)
- The provisions of Directive 96/61/EC concerning integrated prevention and reduction of pollution, Directive 76/464/EEC and 86/280/EEC on discharges of certain dangerous substances and Directive 84/360/EEC on the combating of air pollution from industrial plants apply to PVC and VCM production processes (EC, 2000).
- According to Directive 2000/76/EC on the incineration of waste, an emission limit of 10mg/m³ for hydrogen chloride is established.
- Best available technologies for the production of VCM and suspension PVC have been established, which have led to the adoption of a number of relevant emission limits in OSPAR Decisions. Decisions 98/4 and 98/5 enter into force on 9 February 1999 for new plants and on 1 January 2006 for existing plants (EC, 2000).

- Voluntary Commitments on the sustainable development of PVC are signed by the European PVC industry. One addresses, for example, the reduction of the use of certain heavy metal stabilisers, the mechanical recycling of certain post consumer wastes and the development of further recycling technologies (Andersson, 2005).

3.17.4 Risk Assessment

Environment and Human Health

Exposure

The environment and human health impacts due to PVC applications involve mainly the following sources. Emissions of organic chlorine and mercury during the production and processing of PVC may occur including possible risks due to accidents such as fires. The release of dioxins and furans can be caused by the chlorine alkaline electrolysis and oxychlorination during the production process and during specific thermal processes and in the case of uncontrolled fires (UBA, 1999). The risk assessment of additives of PVC is not regarded here. The most serious environmental impact is found in the disposal and recycling lifecycle stage (see below) (UBA, 1999).

The chlorine in PVC which represents 57% of the weight in the pure polymer resin is produced via the chlorine alkaline electrolysis. Approximately 35% of the chlorine ends up in the PVC after the electrolysis. Stabilizers are used to avoid the loss of chlorine as hydrogen chloride. Production of chlorine *via* the amalgam process involves mercury emissions. As an alternative, membranous processes are preferable in this regard and are increasingly used. The mechanical properties and also stability towards light and heat can be improved by additives, plasticizers etc.

In order to produce PVC the intermediates, ethylene dichloride and vinyl chloride monomer, are synthesized. Although these processes take place in closed systems to a large extent, emissions of chlorine, ethylene, VCM, EDC, HCl and other organic chlorine compounds can occur in the working and outdoor environment, to air and water. Most of these substances are toxic. Therefore, several emission control measures are already in place. Different processes of polymerisation (suspension and emulsion) generate PVC polymer containing monomer residues of no more than 5 ppm vinyl chloride.

Disposal and recycling

The major problem in the recycling of PVC is its high chlorine content of raw PVC (56% of the polymer's weight) and the high levels of hazardous additives added to the polymer to achieve the desired material quality. Additives may comprise up to 60% of a PVC product's weight. Of all plastics, PVC uses the highest proportion of additives.

As a result, PVC requires separation from other plastics and sorting before mechanical recycling. PVC recycling is problematic because of:

- high separation and collection costs;
- loss of material quality after recycling;
- the low market price of PVC recyclate compared to virgin PVC;
- the limited potential of recyclate in the existing PVC market.

PVC feedstock recycling is hardly feasible at present, from an economic or an environmental perspective.

The few PVC products which are recycled are mainly cables (38 000 tonnes) which account for a large part of EEE appliances. However, they are mechanically downcycled resulting in a material that has lower quality. Cable recycling is mainly done because there is a high interest in reusing copper and aluminium. The PVC is often reused in thick-walled products for road safety such as in pedestal rounds, for industrial flooring and as filling material in cover panels. It can not be used as secondary raw material in cables due to safety risks (BiPRO, 2002). During chemical recycling chlorine is set free in form of hydrogen chloride. Chloride can be re-used or needs to be neutralized depending on the recycling process. Compared to landfill and incineration, recycling is preferable as some chloride can be saved.

When PVC plastic is incinerated, toxic substances, including dioxins, may be emitted, and large amounts of solid wastes are produced as slag, ash, filter residues and neutralisation salt residues. However, incineration of PVC is not just a problem because of dioxin emissions. Burning PVC also produces a large number of by-products of combustion, including carcinogens such as vinyl chloride, polychlorinated biphenyls (PCBs), chlorobenzene and other aromatic hydrocarbons such as benzene, toluene, xylene, and naphthalene. Toxic ingredients added to PVC to give it useful properties, such as phthalates are also released during incineration. These are emitted to the air or in the ash that is landfilled.

When PVC is landfilled, PVC additives such as phthalates will eventually leach, posing a risk to groundwater. PVC is durable and has a long lifetime. After disposal, the polymer will not decompose readily or quickly.

Several manufacturers of EEE are committed to achieving phase out of PVC in all their applications proving that substitution of PVC in EEE is possible at least for a large number of applications.

3.17.5 References

- BSEF (2008): Plastics Consumption by Sector, Retrieved April 8th, 2008, from www.bsef.com/recycling/plastic_consumption.
- BiBRO (2002): Behandlungs- und Verwertungswege für PVC- Abfälle, Gesamtbericht, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien Retrieved April 11th, 2008, www.bmlfuw.gv.at/article/articleview/29648/1/6940.
- European Commission (2000): Environmental Issues of PVC, Green Paper, Brussels.
- PE EUROPE GmbH, Institut für Kunststoffkunde und Kunststoffprüfung (IKP), Instituttet for Produktudvikling (IPU), DTU, RANDA GROUP (2004): Life Cycle Assessment of PVC and of principal competing materials, Final Report, Commissioned by the European Commission Brussels, Retrieved April 9th, 2008 from http://europa.eu.int/comm/enterprise/chemicals/sustdev/pvc-final_report_lca.pdf.
- UBA (1999), Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC, Erich Schmidt Verlag, Berlin.

4 Information on substitutes

For those substances that after evaluation of risk assessment data have been considered as potential candidate substances for inclusion in RoHS (see partial conclusions on each substance in Chapter 3), data on possible substitutes and alternative technologies for the respective use in EEE have been analysed in the following chapter. 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. However, the level of detail in the data obtained from industry has not been specific enough to quantify the environmental, economic and social impacts of substitution.

4.1 Substitution of halogenated flame retardants

Halogenated flame retardants are primarily based on bromine and chlorine substances such as brominated aromatic compounds (e.g. TBBP-A), chlorinated paraffins (e.g. MCCPs, SCCPs) and chlorinated cycloaliphatic compounds (e.g. HBCDD).

In general, there are three different types of halogen-free flame retardants that can be used to substitute brominated and chlorinated flame retardants (Döring 2007; Morose 2006):

Inorganic:

This category comprises mainly metal hydroxides like aluminium hydroxide and magnesium hydroxide, and to a much lesser extent other compounds like e. g. zinc borate.

Phosphorous based:

Phosphorus based flame retardants include organic and inorganic phosphates, phosphonates and phosphinates as well as red phosphorus, thus covering a wide range of phosphorus compounds with different oxidation states.

Nitrogen-based:

Nitrogen based flame retardants are typically melamine and melamine derivatives (e. g., melamine cyanurate, melamine polyphosphate, melem, melon). They are often used in combination with phosphorus based flame retardants.

There are different approaches available to reduce the use of halogenated flame retardants. These approaches can be grouped into the following categories:

Substitution of flame retardants:

The halogenated flame retardants are replaced in the polymer material by a drop-in chemical substitute. The drop-in chemical would ideally be cost and performance comparable to the halogenated flame retardant. It is the simplest approach because it typically does not require changes to the polymer material or to the design of the product. This change could be implemented by the polymer processor or compounder.

Substitution of polymer material or resin:

Both the chemical used as flame retardant and the polymer material or resin system are changed. This is a more complex approach than simple flame retardant substitution because it has a greater effect on overall product cost and performance. This change could be implemented by the polymer processor/compounder or the end-product manufacturer.

Redesign of the product:

The actual product design is changed to minimize or eliminate the need for flame retardant chemicals. Examples of product redesign include using fire barrier material, as well as separating or reducing the source of heat from the product. This change could be implemented by the end-product manufacturer.

In the following sections the possibilities of substitution of the halogenated flame retardants TBBP-A, HBCDD, MCCPs and SCCPs are discussed in detail.

4.1.1 TBBP-A

TBBP-A is commonly used as a reactive flame retardant for epoxy resin applications such as (1) printed wiring board laminates and (2) encapsulation of electronic components.

Printed circuit boards are used in a wide variety of end-use markets as computers & peripherals, communication systems, consumer electronics and other applications such as business machines and industrial equipment.

Epoxy embedded compounds are used to enclose, encapsulate, or seal an electrical or electronics component in a protective matrix. This matrix protects the component from environmental hazards such as moisture, dirt, and oxygen. The matrix can also provide enhanced mechanical strength and dielectric insulation.

TBBP-A is further used – in a much smaller extent – as additive flame retardant for acrylonitrile butadiene styrene (ABS) products to meet Underwriters Laboratories (UL) 94 fire safety standards. ABS applications include various electrical and electronic equipment applications as television and computer monitor enclosures.

Substitution of TBBP-A in epoxy resin for printed wiring boards and encapsulations

Epoxy resin laminate for printed wiring boards need to fulfil several key performance requirements as, for example, thermal properties (e.g. glass transition temperature – Tg); mechanical properties (e.g. coefficient of thermal expansion – CTE); and electrical properties (e.g. dielectric constant). The acceptable values and relative importance of these properties are determined by the particular design requirements (e.g. board thickness), processing capabilities (e.g. multiple lamination cycles), and performance requirements (e.g. extended thermal cycling) for each printed wiring board application.

The flame retardant material can have an effect on many of these properties.

Fire safety standards in the U.S. for electronics products are developed by the Underwriter's Laboratory (UL). UL has developed several performance standards for electronics products and components regarding their resistance to ignition and flame propagation. The chief fire safety standards for electronic enclosures are the UL 94 component standards. The UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances is the relevant standard for printed wiring boards. The UL 94 component standards range from UL94 HB (the lowest standard), which involves a horizontal burn; to successively more stringent vertical burning tests (Class UL 94 V-2, V-1, V-0 and 5V).

There are several National Electrical Manufacturers Association (NEMA) classes of fire retardant laminate materials used for printed wiring boards. For example, FR-1 is made from a phenolic resin with paper reinforcement. FR-4 is made from an epoxy resin with glass cloth reinforcement. FR-4 printed wiring boards are widely used in the electronics industry.

In general, when using TBBP-A alternatives for printed wiring boards it is a challenge to achieve the UL 94 V-0 rating for FR-4 type printed wiring boards because thermal stability, moisture resistance, and other properties may be compromised.

I) Substitution of TBBP-A by other, non-halogenated flame retardants with epoxy resin as base material (Döring, 2007; Morose, 2006):

   a) Reactive flame retardants:

      - DOPO (Dihydrooxaphosphaphenantrene) and its derivates which are cyclic hydrogenphosphinates,

        DOPO is a cyclic hydrogenphosphinate containing a P-H bond. It is mono-functional, but several modifications are possible, which, when properly catalyzed, can be grafted to C=C linkage or reacted with epoxy groups. Today, DOPO can be regarded as the major building block used to make phosphorus containing epoxy resins (Tg up to 150°C). DOPO is commercially available from different suppliers and global capacities have consequently increased over the past 2 years to respond to the increasing market demand from PCB.

      - Poly(1,3-phenylene methylphosphonate)

        Due to its hydroxyl groups it can react into the polymer and act as a curing agent for epoxies. It is recommended in combination with Aluminium-tri-hydroxide (ATH) or Aluminium-oxide-hydroxide (AOH). High temperature stability is reported (high Tg, pressure cooker test).

   b) Additive flame retardants:

      - Metal phosphinates

        Metal phosphinates can be used for rigid as well as flexible PWB. Unlike most other phosphorus containing compounds, the metal phosphinate is not hygroscopic, not toxic, has an extremely low solubility in water and common solvents and does not hydrolyse in the presence of water. The latter point is especially crucial, since the release of phosphoric acid is a not tolerable in E&E applications. Further key aspects are the high phosphorous content (> 23%) and its good thermal stability (> 300°C) which makes it compatible with lead-free soldering operations. Electrical properties show virtually no impact on Dk / Df even at frequencies well above one GHz. However, the metal phosphinate can not be used alone to achieve a UL 94 V0 classification, therefore it is usually combined with N-synergist such as Melamine polyphosphate, with modified (phosphorous or nitrogen containing) epoxy resins or blends with other polymers (cyanate esters, benzoxazines, PPE or others). Metal phosphinates are also suitable for flexible printed circuit boards (FPC).

- Melamine polyphosphate, used in combination with other FRs (e.g. phosphinates, minerals)

  Melamine polyphosphate has a good thermal stability and low influence on Tg.

- Metal hydroxides e.g. Aluminium Trihydroxide (ATH, $Al(OH)_3$); Alumina monohydrate (AlOOH); Magnesium hydroxide $Mg(OH)_2$

  Metal hydroxides act by consuming energy during thermal decomposition, releasing water and forming an oxide layer. Thereby they cool the polymer, dilute the combustion gasses, and shield the resin substrate by the formed oxide layer. Furthermore, this oxide layer adsorbs soot particles leading to low smoke levels. A big advantage of these mineral Flame retardants is their effect to reduce the CTE down to very low values (< 40 ppm are possible).

  Aluminium trihydroxide is the largest volume flame retardant used in the world. When heated to 220°C, ATH decomposes into 66% alumina and 34% water. This irreversible process helps make ATH an effective flame retardant. High loadings of ATH (combined with other flame retardant materials) and sometimes magnesium hydroxide have been used as alternatives to TBBP-A. To be effective as a flame retardant, ATH has to be used in high loadings, typically 40% to 60% by weight. ATH is relatively low in cost. However, since it requires high loadings, it cannot be used in applications where the high loadings may critically affect polymer processing and physical properties. In addition, because of the relatively low decomposition temperature of ATH, it cannot be used when processing temperatures exceed 180°C. No significant environmental or health issues were identified for ATH.

  Magnesium hydroxide undergoes an endothermic reaction that releases its water at approximately 330°C. Therefore, it can be used when processing temperatures are too high for use of ATH. No significant environmental or health issues were identified for magnesium hydroxide.

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

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

- Thermosetting plastics:

  Alternative thermosetting polymers can be used, on their own or blended e.g.

  – Cyanate esters (CE)

  – Bismaleimide Triazine (BT)

  – Thermoset Polyphenylenether (A-PPE)

  – Polyphenylenether (PPE) or Polyphenylenoxide (PPO) blended with epoxies

  – Poly(tetrafluoroethylene (PTFE): for high frequency applications

  DeBoysère (2006) gives an overview on commercially available halogen-free materials.

- High Temperature Thermoplastic resins made of Polyether Imide (PEI) and Polyethersulfone (PES)

  → High Temperature Thermoplastics (“HTT boards”)

  HTT Boards offer improved machining properties (drilling, milling), high thermal resistance, excellent HF properties, and are light weight. The boards have only about one third of the environmental burden compared with thermosetting PCB (e.g. FR-4) because of higher resource efficiency and more efficient production process. HTT boards are intrinsically flame retardant at a level equivalent to UL V-0 (Öko-Institut, 2007).

  In contrast to common epoxy resins and thermosetting plastics, thermoplastic resins can be recycled. It is disadvantageous with regard to substitution that inherently flame-retardant resins are often more expensive than the common epoxy resins. However, when shifting from the material level to the level of assembled printed circuit boards, costs may be equal or even lower for HTT boards (Öko-Institut, 2007).

  On basis of

DeBoysère (2006) concludes that a wide range of materials of halogen-free technologies are currently available and further research is expected to result into new raw materials. This includes halogen-free additives, as well as resin backbones. All have different mechanical and electrical properties and different impact on cost. To a certain extent, costs are expected to decrease with volumes.

A special case may be printed wiring boards (PWB) for high frequency applications (up to 1000GHz) that are primarily used in WEEE Cat. 9 (Monitoring & Control Instruments).

Experts from the Test & Measurement Coalition pointed out that for these high frequency applications printed wiring boards made of halogen-free base material are not yet applicable.

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 2008.

The “iNEMI BFR-Free PCB Project” of the industry consortium iNEMI (International Electronic Manufacturing Initiative) investigates the technical viability of halogen-free printed circuit board materials. The project aims to promote standards development by establishing materials, manufacturing, assembly, and test guidelines for bromine flame retardant (BFR)-free printed wiring boards based on market segment requirements and technical, commercial, and functional viability.

The High Density Packaging User Group (HDPUG) runs a project to create a distributed database containing information on the properties and availability of halogen-free electronic components and materials (HDPUG 2008).

Substitution of TBBP-A as additive FR in ABS

TBBP-A is used as additive flame retardant for acrylonitrile butadiene styrene (ABS) products as for example television and computer monitor enclosures.

Electronic enclosures can also be made of other types of polymer resins such as high impact polystyrene (HIPS), polycarbonate / ABS blends (PC/ABS) and polyphenylene oxide / HIPS blends (PPO/HIPS) in combination with other flame retardants.

International standards provide that the plastic materials used for these housings usually should meet high fire safety standards such as UL 94 V 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. In addition to the required level of fire safety, the used polymer resins have to meet additional criteria such as processability, thermal stability, mechanical properties, hydrolytic stability and recyclability. This combination of requirements can be fulfilled by using the following phosphorous based flame retardants:

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

These four phosphorous compounds are commonly used in PC/ABS and PPO/HIPS blends.

Thus, electronic enclosures made of ABS containing TBBP-A as flame retardant can be replaced by enclosures made of PC/ABS or PPE/HIPS containing phosphorous based flame retardants (Döring, 2007).

4.1.2 HBCDD

HBCDD is used as additive flame retardant in HIPS for electronic enclosures.

As described above in Section 4.1.1, electronic enclosures can alternatively be made of PC/ABS or PPE/HIPS blends using phosphorous based flame retardants such as TPP, RDP, BDP or BAPP instead of HBCDD.

KEMI (2007) summarizes in its strategy paper for limiting risks of HBCDD that a copolymer of HIPS and polyphenylene oxide (PPO) with a suitable flame-retardant can in many cases substitute HIPS with HBCDD, though it will not exactly match all the properties, e. g. UV stability. However, the addition of PPO improves flame retardancy. Triphenyl phosphate (TPP) is one flame-retardant that could be used in PPO/HIPS. The cost of substitution is dependent on the price of the raw materials, research and development costs, and possible changes of moulds and other tools. The latter, if necessary, may be a significant part of the costs. These costs can be lowered if the introduction of substitutes takes place when the moulds are changed along with periodic design changes. As an indication of raw material prices it is estimated that going from HIPS with a brominated flame-retardant to PPO/HIPS with a halogen-free flame-retardant would increase the raw-material price with about 4-5 EUR for a full enclosure of an average TV-set.

There is insufficient data for a firm conclusion on the health and environmental aspects of TPP, but there is no evidence of concern with respect to CMR. TPP is not considered persistent or bioaccumulative according to the PBT criteria, but data are inconclusive on the T-criteria.

KEMI (2007) concludes that for the use of HBCDD in HIPS, there seem to be alternatives available that are technically viable and pose less risk to human health and the environment.

4.1.3 Other halogenated flame retardants

Further applications of halogenated flame retardants (other than TBBP-A and HBCDD) include the uses in wire & cables and in electric installations & components.

Table 22 gives a general overview of the different halogen-free flame retardants that can be used in cable compounds (Döring, 2007).

Table 22 Overview of the different halogen-free flame retardants used in cable compounds (Döring, 2007)

Flame retardant	Polymers	Applications and effectiveness
Metal hydroxides: Aluminium-tri-hydroxide (ATH) Magnesium-dihydroxide (MDH) Boehmite (AOH) (aluminium-oxide-hydroxide)	Low density polyethylene Ethyl vinyl acetate Polyolefins	In fire, these mineral FRs decompose, absorbing energy, releasing water (reducing fire intensity and diluting fire gases), and causing charring (fire barrier)
Phosphorous flame retardants	Used in fire resistant coatings for cables	The coatings form a charred foam layer on the cables
Zinc borate	Synergist with ATH	-
Red phosphorus	Polyolefins	-
Phosphate esters (e. g. Tricresyl Phosphate TCP)	Rubber	Flame inhibition and charring fire resistance properties of phosphorus
Melamine cyanurate, melamine phosphate,	Polyamides Polypropylene	A low dosing between 7–15 % results in polymer decomposing (PA) without flaming
Intumescent products based on Ammoniumpolyphosphate (APP)	Polyolefins, Thermoplastic Elastomers	With loading of 15–30 % new developed products can achieve highest fire safety standards (UL 94 V0) by formation of an insulating fire barrier me retardants used in HFFR cable compounds.

Electrical installations and components comprise connectors and switches/switchgear made of different plastics. Which plastic is ultimately chosen to design a specific part or component depends very much on the performance of a plastic with respect to mechanical, electrical and fire properties. Fire safety is particularly important for plastics used in components that (potentially) generate heat due to the use of electricity or in case of malfunctions.

In Europe the fire safety requirements for connectors and switches are determined by technical standards from the International Electrotechnical Commission (IEC). Some of the most important standards include IEC 60898 for circuit breakers, IEC 60947 for industrial control equipment and IEC 60335 for the area of domestic appliances. Besides the IEC standards many of the requirements from the American Underwriters Laboratories (UL) have been adopted in Europe and Asia as well. UL 94 V0 for example, is probably the most commonly used flammability requirement anywhere in the world. Depending on the end application, for IEC standards approval is based on either material testing or on testing the finished component, whereas under UL tests are always performed on the material only. Despite the differences between these test methods one common denominator in all tests is the specified ignition source and the way a sample is exposed to the ignition source. Choosing the right polymer for an electrical connector or switch evolves around finding the right balance between fire safety on one hand and mechanical and electrical properties on the other hand. A variety of halogen-free flame retardants are available today that allow compounders to optimize their formulations (Table 23).

Table 23 Overview of halogen-free flame retardants for electric installations (Döring, 2007)

Flame retardant	Polymers	Applications and effectiveness
Metal phosphinates combined with N-synergists	Glass fibre reinforced polyamides and polyesters	High phosphorus content (> 23%), no affinity to water and a good thermal stability (up to 320 °C) which make them compatible with lead-free soldering operations.
Melamine polyphosphate (MPP)	Glass fibre reinforced polyamides 6,6	Added at ca. 25 % for UL 94 V0 performance. It has a good thermal stability (ca. 300 °C). MPP is often used as synergist in combination with phosphorus FRs.
Melamine cyanurate (MC)	Unfilled and mineral filled polyamides	UL 94 V0 can be achieved with 10 to 15 % in unfilled PA and up to 20 % for UL 94 V2 in low glass filled PA 6. MC is often used as synergist in combination with phosphorus FRs.
Red phosphorous	Glass fibre reinforced polyamides 6,6	Addition level of 5 to 8 %. Due to its inherent colour, compounds are limited to red or black colours. In addition, precautions against degradation have to be taken.
Aryl phosphates and phosphonates	Styrenic blends	Addition level of 10 to 20 % for UL 94 V0. They are often used as co-components in FR-formulation. Their limitations are possible plastisicing effects and a certain volatility at high processing temperatures. Blooming can have a negative influence on electrical properties.
Magnesium hydroxide (MDH)	Low glass fibre polyamides 6	High filler levels of about 45 to 50% are necessary to reach UL 94 V0. limited temperature stability
Ammonium polyphosphate in combination with nitrogen synergists	Polyolefins	Addition levels of ca. 20 % to 30 %.

A market analysis performed by COWI in January-April 2006 showed that a number of compounds were possible as substitutes for deca-BDE in various polymers (see Table 24). The proposed halogen-free flame retardants can also be used as substitutes for TBBP-A and HBCDD.

Table 24 Summary table on flame retardants for relevant V-0 grade plastics in EEE (Lassen, 2006 in Danish EPA, 2007)

Halogen-free flame retardants	**Enclosures**				**Connectors, etc**		**Wires**	
	HIPS	**ABS**	**PC/ABS**	**PPE/ HIPS**	**PA**	**PBT/PET**	**PP**	**PE**
Resorcinol bis(diphenylphosphate) (RDP)			X	X				
Bisphenol A bis(diphenylphosphate) (BDP)			X	X				
Triphenyl phosphates (TPP)			X	X				
Intumescent FR systems based on phosphor and nitrogen compounds							X	X
Red phosphorus					X			X
Melamine cyanurate					X		X	
Melamine polyphosphate					X			
Organic phosphinates					X	X		
Magnesium dihydroxide					X		X	

Thus, a number of readily available alternatives exist that allows for the substitution of TBBP-A, HBCDD and other halogenated flame retardants in a range of flame retardant applications.

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.

However, in several studies the (eco-) toxicological and environmental properties of halogen-free flame retardants have been evaluated.

The German Federal Environmental Agency (Umweltbundesamt, UBA) examined the toxicological and ecotoxicological properties of several halogen-free flame retardants (UBA, 2000; UBA, 2003b).

The Danish EPA performed a survey to identify and describe suitable alternatives to the brominated flame retardant DecaBDE and subsequently initiated a health and environmental assessment of selected alternatives to DecaBDE as proposed by the survey (EPA Denmark, 2007). The study did not develop a full evaluation of to what extent negative environmental or health impacts caused by substitution are likely to outweigh the human and environmental benefits of the substitution, but identified the existence of flame retarding alternatives to DecaBDE with less or equal environmental and health impacts. The results can also be transferred to other halogenated flame retardants as TBBP-A and HBCDD.

The Illinois Environmental Protection Agency issued a "Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues" (Illinois EPA, 2007). The authors evaluated human health risks from cancer, reproductive/ developmental effects, systemic toxicity, and local (point-of-contact) effects; environmental risks from acute and chronic aquatic effects and acute toxicity to terrestrial species (chronic toxicity being addressed by the human health endpoints other than cancer); and whether a chemical displayed the characteristics of a Persistent, Bioaccumulative, and Toxic (PBT) chemical, in order to adequately compare the toxicities of DecaBDE and potential alternatives. The results were then used to place the chemical alternatives into classes of overall concern: Potentially Unproblematic, Potentially Problematic, Insufficient Data, and Not Recommended. It is concluded in the report that there is insufficient toxicity data available for the alternatives to say with certainty that they pose little or no risk and are therefore "safe" to use as flame retardants. However, some of the chemical alternatives do appear to be safer than DecaBDE. The same substances come into consideration as substitutes for other halogenated flame retardants as TBBP-A and HBCDD.

JRC-IHCP-ECB prepared a report on "Alternatives to DecaBDE (Deca Bromodiphenyl ether) used in polymeric applications in electrical and electronic equipment" (EEE) commissioned by Directorate General Environment (DG ENV) (ECB, 2007). In this study, the JRC-IHCP-ECB has reviewed the production processes of DecaBDE and explored the availability of potential DecaBDE alternatives used in polymeric applications for EEE (cost of substitution and recyclability of alternatives was outside the scope of the study). The report concludes that substitutes do exist on the market for DecaBDE for the proposed applications and that many large electronic manufacturers claim to have moved to bromine-free alternatives. In addition literature data suggest that potential adverse environmental and human health effects of at least some substitutes may be minimal. However key data and information gaps in comprehensive risk assessments and hazard classification still exist, as well as uncertainties related to the potential impacts of degradation products of both DecaBDE and its substitutes. Again, the results of this study are also relevant to other halogenated flame retardants as TBBP-A and HBCDD.

The results of the above-mentioned studies are summarised in Table 24.

Table 25 Evaluation of (eco-) toxicity and environmental data of halogen-free flame retardants

Flame retardant	Abbreviation	CAS No.	Classification[68]	Evaluation results	Summary evaluation
Organic phosphorus-based flame retardants					
Resorcinol-bis-diphenyl-phosphate	RDP	57583-54-7	Not classified.	No data concerning occurrences in environmental samples. Analyses based on animal experiments are incomplete. Studies on cancerogenicity are missing. Disposal is unproblematic. Data on behaviour during recycling is missing (UBA, 2000). No concern for reproductive/developmental effects; no chronic aquatic toxicity data; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include cancer, chronic systemic effects, and chronic aquatic toxicity studies (IEPA, 2007).	Potentially unproblematic (IEPA, 2007)
Bisphenol A diphenyl phosphate	BDP	181028-79-5	Not classified.	Low concern for most endpoints based on existing data and professional judgment; key data deficiencies include cancer, two-generation reproductive / developmental effects, and chronic aquatic toxicity studies; some concern due to generation of Bisphenol A, a chemical identified by the Agency as a probable endocrine disruptor (IEPA, 1997), as a breakdown product, although no data on potential amounts were found (IEPA, 2007).	Potentially unproblematic (IEPA, 2007)
Triphenyl phosphate	TPP	115-86-6	Not classified.	There is insufficient data for a firm conclusion on TPP, but there is no evidence for concern with respect to CMR of TPP. TPP is not considered persistent or bioaccumulative according to the PBT criteria. Many data are available on toxicity, and one test result possibly meets the T criteria. The validity of this dataset has been questioned and the results should be confirmed (DEPA, 2007).	The use of TPP as a flame retardant in the assessed applications does not appear to infer additional hazard to the environment or human health when compared to DecaBDE (DEPA, 2007).

---

[68] Classification according to Directive 67/548

Flame retardant	Abbreviation	CAS No.	Classification[68]	Evaluation results	Summary evaluation
				High Concern for acute and chronic aquatic toxicity (very wide range of fish lethality levels); Low Concern for other effects based on existing data and professional judgment; key data deficiencies include cancer and two-generation reproductive/developmental studies (IEPA, 2007).	Potentially problematic (IEPA, 2007)
Tricresyl phosphate	TCP	1330-78-5	Not classified.	High Concern for acute and chronic toxicity to fish; No Concern for cancer risk; no data for local effects; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include skin and eye irritation and two-generation reproductive/development studies (IEPA, 2007).	Potentially problematic (IEPA, 2007)
Diphenyl cresyl phosphate	DCP	26444-49-5	Not classified.	Moderate Concern for aquatic toxicity and no data for fish chronic toxicity; Moderate Concern for skin irritation and no eye irritation data; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include cancer, two-generation reproductive/developmental, eye irritation, and fish chronic toxicity studies (IEPA, 2007).	Potentially problematic (IEPA, 2007)
Tetrakis(hydroxymethyl) phosphonium chloride		124-64-1	Not classified.	High Concern for acute and chronic toxicity to algae; Moderate/High Concern for local effects (skin irritant and sensitizer, but test with humans shows treated fabric not irritating to skin, and severe eye irritant); No Concern for cancer risk; Moderate Concern for systemic toxicity for liver and neurological effects; Low Concern for other effects; miscible with water, potential risks to groundwater; key data deficiency is two-generation reproductive/developmental study (IEPA, 2007).	Potentially problematic (IEPA, 2007)
Diethylphosphinic acid, aluminium salt		225789-38-8	Not classified.	Data are not sufficient to conclude on carcinogenic, reproductive or endocrine disruption potential. There are no indications of mutagenic or sensitising potential of diethylphosphinic acid (aluminium salt). Based on the available data, the tested FR product containing is considered to be very persistent (vP), but not to meet the criteria for bioaccumulation. The available data indicate that diethylphosphinic acid, aluminium salt, is not acutely toxic at concentrations up to the water solubility limit, and has a low acute toxicity towards	For diethylphosphinic acid, aluminium salt, few data are available from the manufacturer. The available studies but do not suggest that the compound should be more hazardous to man or environment than DecaBDE (DEPA, 2007).

Flame retardant	Abbreviation	CAS No.	Classification[68]	Evaluation results	Summary evaluation
				aquatic organisms (DEPA, 2007). Low Concern for local effects and acute environmental toxicity; insufficient data for all other effects; key data deficiencies include cancer, reproductive / developmental, and systemic effects studies, and environmental fate data (IEPA, 2007).	Insufficient data (IEPA, 2007)
Inorganic phosphorus-based flame retardants					
Red phosphorus	RP	7723-14-0	Not classified.	Additional hazards caused by red phosphorus used as flame retardant play a minor role considering natural occurrences of phosphorus. Toxicity is low except for skin irritation caused by direct contact with red phosphorus. Phosphor oxide and phosphorous acid are released in a case of fire. Data on recycling of phosphorous-containing plastics is missing (UBA, 2000). There are no studies available on carcinogenicity, mutagenicity, reproduction toxicity, endocrine effects or sensitisation. Based on the available data, red phosphorus is considered to meet the P and vP criteria due to the inorganic nature of the substance. The data are insufficient for evaluation of the B and T criteria. At a screening level, red phosphorus does not meet the T criteria. Red phosphorus has been marketed in the EU for many years and there is no requirement of new data for existing substances according to EU regulation (DEPA, 2007). High Concern for acute aquatic toxicity; probably Low Concern for local effects but no skin sensitization data available; insufficient data for all other effects; key data deficiencies include cancer, reproductive/developmental, systemic effects, and chronic aquatic toxicity studies (IEPA, 2007).	Red phosphorus has been used as a flame retardant for a number of years. The available studies are limited, but do not suggest that RP should be more hazardous to man or environment than DecaBDE (DEPA, 2007). Insufficient data (IEPA, 2007)
Ammonium polyphosphate	APP	68333-79-9; 14728-39-9	Not classified.	Due to the application as additive flame retardant in polyurethane, release into environmental media is possible. However, no relevant hazards are caused. Toxic effects are not mentioned. Merely irritations of the skin and the mucous membrane are reported. Nitrogen oxide and ammonia are formed in fire. Its behaviour	Insufficient data (IEPA, 2007)

Flame retardant	Abbreviation	CAS No.	Classification[68]	Evaluation results	Summary evaluation
				during recycling is favourable (UBA, 2000). Probably Low Concern for acute environmental toxicity (no terrestrial data but rapid breakdown to ammonia and phosphate should produce relatively low toxicity); no data for other endpoints, although toxicities of ammonia and phosphate are low for most effects (IEPA, 2007).	
Nitrogen-based flame retardants					
Melamin cyanurate	MC	37640-57-6	Not classified.	This flame retardant is used additively. Release into environmental agents is possible. Environmental agents have not been analysed. Toxicology of melamine cyanurate has not been examined. Toxic fumes such as hydrocyanic acid and isocyanate are formed in a case of fire (UBA, 2000).	Recommendation impossible due to a data deficit (UBA, 2000)
Melamine	M	108-78-1	Not classified.	Bladder tumors found in male mice and rats at very high doses and only when bladder stones present (potentially not related to melamine but may be a general response to a foreign substance), cancer risk may be low; No Concern for environmental effects; insufficient data for other effects; key data deficiencies include additional cancer studies, reproductive/developmental, neurotoxicity, and immunotoxicity studies (IEPA, 2007).	Insufficient data (IEPA, 2007)
Mineral-based flame retardants					
Aluminium trihydroxide	ATH	21645-51-2	Not classified.	There is no measurable increase with regard to the aluminium content in environmental samples as a consequence of the application as flame retardant. No indication of human- or ecotoxicological problems (UBA, 2000). No cancer data, but risk likely to be low based on professional judgment; Low Concern for other effects based on existing data and professional judgment (human exposure data from antidiarrheal and antacid uses); key data deficiencies include cancer, neurological effects, and chronic aquatic toxicity studies; acute aquatic toxicity likely only at very low pH (IEPA, 2007).	Potentially unproblematic (IEPA, 2007)

Flame retardant	Abbreviation	CAS No.	Classification[68]	Evaluation results	Summary evaluation
Magnesium hydroxide	MDH	1309-42-8	Not classified.	No cancer or reproductive/developmental data, but risk likely to be low based on professional judgment; Low Concern for other effects based on existing data and professional judgment (human exposure data from food, medicinal, and cosmetic uses); key data deficiencies include cancer, reproductive/developmental, and chronic aquatic toxicity studies (IEPA, 2007).	Potentially unproblematic (IEPA, 2007)
Other flame retardants					
Zinc borat		1332-07-6	Not classified.	High Concern for effects on blood; High Concern for acute aquatic toxicity; no data for cancer, reproductive/developmental effects, and chronic aquatic toxicity (IEPA, 2007).	Not recommended (IEPA, 2007)
Boric acid		10043-35-3		Moderate Concern for reproductive/developmental effects based on testicular and developmental effects; Moderate Concern for skin and eye irritation; no data for cancer and chronic aquatic toxicity, Low Concern for other effects; key data deficiencies include cancer, skin sensitization, and chronic aquatic toxicity studies (IEPA, 2007).	Potentially problematic (IEPA, 2007)
Polytetrafluoroethylene		9002-84-0		High Concern for known respiratory effects of toxic thermal degradation products; Moderate Concern for cancer effects, although finding of tumors only in areas of implanted Polytetrafluoroethylene raises doubt about relevance to human cancer risk from use as a flame retardant; High Concern for lung irritation when heated; no data available for reproductive/developmental effects and acute and chronic aquatic toxicity; bird mortalities reported from overheated Teflon cookware (IEPA, 2007).	Not recommended (IEPA, 2007)

IEPA, 2007: Illinois EPA (2007)

DEPA, 2007: EPA Denmark (2007)

References

- Baur, E.; Brinkmann, S.; Osswald, T.; Schmachtenberg, E.: Saechtling Kunststoff Taschenbuch. 30. Auflage, Carl Hanser Verlag, München 2007.
- De Boysère, J. (2006): Halogen-free laminates – the technology is there for an emerging market.. EIPC Summer Conference, Venice, June 8-9th 2006. http://www.flameretardants-online.com/news/downloads/over_english/2006_06_halogen_free.pdf
- De Boysère, J. (2007): Overview of Alternatives to BRF in E&E Applications – Case Study of Printed Wiring Boards. Fa. Clariant. Konferenzbeitrag BFR 2007, 4th International Workshop on Brominated Flame Retardants, Amsterdam, April 24-27th 2007.
- Döring, M. & Diederichs, J. (2007): Halogen-free flame retardants in E&E applications, Forschungszentrum Karlsruhe, Germany
- ECB (European Chemicals Bureau) (2007): Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to DecaBDE. http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf
- EPA Denmark (Danish Environmental Protection Agency) (2007): Health and environmental assessment of alternatives to Deca-BDE in electrical and electronic equipment. Report. http://www.mst.dk/Udgivelser/Publications/2007/01/978-87-7052-351-6.htm
- EPA USA (United States Environmental Protection Agency) (2006): Flame Retardants in Printed Circuit Boards Partnership. Design for Environment. http://www.epa.gov/dfe/pubs/projects/pcb/index.htm
- HDPUG (2008): Halogen Free Properties Project for Electronics Products. http://www.hdpug.org/sites/38788/pdf/hdp_hf_project_press_release.pdf
- Illinois EPA (2007): Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues; A report to the Governor and the General Assembly; http://www.epa.state.il.us/reports/decabde-study/index.html
- iNEMI (International Electronic Manufacturing Initiative) (2007): Halogen-Free Project. http://www.inemi.org/cms/projects/ese/halogen_free_PhasesII-III.html
- KEMI (2005): Survey and technical assessment of alternatives to decabromodiphenyl ether (decaBDE) in plastics. Report No. 1/05. http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport1_05.pdf

- KEMI (2006): Survey and technical assessment of alternatives to TBBPA and HBCDD. Report No. 1/06. https://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_06.pdf
- KEMI (2007): Strategy for limiting risks, Revision 1 – Hexabromocyclododecane (HBCDD), 18 December 2007, Swedish Chemicals Agency, Sweden; ES-25a-2007 Rev.1.
- Lassen C. (2006): Use of deca-BDE and its alternatives in electrical and electronic equipment. Preliminary list of alternatives. COWI. 25-1-2006.
- Lowell Center for Sustainable Production (2005): Decabromodiphenylether – an investigation of non-halogen substitutes in electronic enclosures and textile applications. University of Massachusetts, Lowell. http://www.sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf
- Marzi, T. & Beard, A. (2006): The ecological footprint of flame retardants over their life cycle- A case study on the environmental profile of new phosphorus based flame retardants. Flame Retardants 2006 Conference. Interscience. ISBN 0954121678. pp. 21-30
- Morose, G. (2006): An overview of alternatives to Tetrabromobisphenol A (TBBPA) and Hexabromocyclododecane (HBCD). Lowell Center for Sustainable Production, University of Massachusetts, Lowell. http://sustainableproduction.org/downloads/AternativestoTBBPAandHBCD.pdf
- Öko-Institut e.V. (2007): Entwicklung von thermoplastischen Leiterplatten als Beitrag zur Kreislaufwirtschaft; Endbericht der Qualifizierungsphase.
- UBA – Umweltbundesamt (2000): Erarbeitung von Bewertungsgrundlagen zur Substitution umweltrelevanter Flammschutzmittel. Band III: Toxikologisch-ökotoxikologische Stoffprofile ausgewählter Flammschutzmittel. UBA-Text 27/01.
- UBA – Umweltbundesamt (2001b): Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals; Results and summary overview; Report No. UBA-FB 000171/1
- UBA – Umweltbundesamt (2001c):: Erarbeitung von Bewertungsgrundlagen zur Substitution umweltrelevanter Flammschutzmittel. Band II: Flammhemmende Ausrüstung ausgewählter Produkte – anwendungsbezogene Betrachtung: Stand der Technik, Trend, Alternativen. UBA-Text 26/01. http://www.umweltbundesamt.de/uba-info-medien/mysql_medien.php?anfrage=Kennummer&Suchwort=1966
- UBA – Umweltbundesamt (2001d): Erarbeitung von Maßnahmenvorschlägen zur Substitution umweltrelevanter Flammschutzmittel bei Leiterplatten, Außengehäusen für IT- und TV-Geräte sowie Polyurethan-Dämm- und Montageschäumen. Workshop-Berichte.

4.1.4 Medium-chained chlorinated paraffins (MCCPs)

The main uses of MCCPs are as secondary plasticizers / softeners and as flame retardants in PVC. In addition, MCCPs are used as lubricants and additives in metal working/cutting.

Where MCCPs are only used as softeners (without a flame-retarding function), the phthalates DINP and DIDP are mentioned as possible alternatives to MCCPs. However, as pointed out in Chapter 3.9, DINP and DIDP have structural similarities to DEHP which itself is considered as hazardous substance and is proposed as candidate substance. Therefore DINP and DIDP are not recommended as suitable substitutes to MCCPs. Further alternative plasticizers for PVC are described in Section 4.2: adipates, citrates, (organo)phosphates, trimellitate and epoxidised soybean oil.

In case a flame-retarding function is also required, additive flame retardants (see Section 4.1.1) need to be added together with the halogen-free softeners. In cable sheathing aluminium trioxide (ATO) together with antimony trioxide as synergist are used as flame retardants.

For some applications, phosphates are proposed as alternatives to MCCPs because phosphates have both softening as well as flame retarding properties. (UBA, 2003). The softening effect of phosphates is, however, less efficient than that of MCCPs or phthalates. Therefore, higher amounts of phosphate need to be added resulting in higher costs.

As pointed out in Section 4.2, the use of plastics that show elastic properties without addition of any plasticizer is preferred to the use of alternative plasticizers. Alternative polymer materials are polyolefines (namely polyethylene (PE) and polypropylene (PP) and ethyl-vinylacetate (EVA). As polyolefines and EVA are not inherently flame retarded, in contrast to PVC, additional flame retardants would need to be added if flame retardancy of the polymer materials is required (see Section 4.1.1).

MCCPs are also used as lubricants and additives in metal working. In many of the metal working operations chlorinated paraffins can be substituted by sulphur- or phosphorous containing additives (UBA, 2003b):

Various sulphur-organic compounds are used as additives: sulfurised hydrocarbons, ester, alcohols, olefins, fatty acids, fatty acid esters basing both on mineral resources and renewable primary products. Polysulphides are considered to be particularly efficient (e.g. sulfurised polyisobutene, polypropylene or polystyrene).

In addition, various organophosphorous compounds are applied as additives in cooling lubricants:

- Phosphorous acid esters (Triphenyl phosphate, tri-ethylhexyl phosphate, etc.);
- Aryl phosphates;
- Mono- and diester of phosphorous acid;
- Phosphonic acid.

Combinations of different compounds are also used to achieve synergistic effects (e.g. phosphoric acid ester together with sulphur additives).

References

- UBA (2003a): Guidance for the use of environmentally sound substances, Part 5.1: Plasticizers.
- UBA (2003b): Guidance for the use of environmentally sound substances, Part 5.5: Extreme pressure additives.

4.1.5 Short-chained chlorinated paraffins (SCCPs)

The use of SCCPs in several main applications (e.g. as metal working fluid) has already been restricted by Council Directive 76/769/EC and by REACH Annex XVII (item 27) and consequently substitution of SCCPs has taken place in most areas, inter alia by MCCPs in metal working processes. Due to the fact that MCCPs themselves are considered as hazardous substances, other substitutes (e.g. sulphur-organic and/or organophosphorous substances) are now proposed as additives in cooling lubricants for metal working operations. For details please refer to Section 4.1.4.

For the remaining uses of SCCP as flame retardant in power supplies and plasticizer in connector wires (as indicated by one stakeholder), the use of halogen-free flame retardants or inherently flame retarded polymer materials (as described in Section 4.1.1) and the use of alternative plasticizers is recommended (as described in Section 4.2)

4.2 Phthalates

Phthalates are mainly used as plasticizers (or softeners) in plastics, especially in flexible PVC (e.g. in cables and other flexible components). Substitution is possible by either using alternative plasticizers or by using plastics that show elastic properties without addition of plasticizers.

Alternative plasticizers

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)phosphate, Tri(2-ehtylhexyl) phosphate and Tri-2-ehtyl-trimellitate are already used as plasticizer 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 26 and Table 27. 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. (Symbols: ● identified potential hazard, ○ no identified potential hazard, and - no data available.

Table 26 Inherent properties of alternative plasticizers (data compiled by COWI, 2001)

Name of substance	CAS No.	Humans			Environment		
		Acute & local effect	CMR[d]	Sensiti-sation	Persistence Bioaccumulation		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 soy-bean oil	8013-07-8	-/○	○	○	○	-	● toxic
Dipropylene gly-col 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 environm.).

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 27 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.

The Annex XV dossiers of BBP and DPP prepared by Austria and published by ECHA summarise information on alternative substances for these two softeners in PVC and in other uses (Austria 2008a, 2008b):

During the last years, chemical industry has partly been replacing DBP and BBP with DINP (Di-isononyl-phthalate, CAS No. 58033-90-2) and DIDP (Di-isodecyl-phthalate, CAS No.

68515-19-1). Those two phthalates are not classified as reproductive toxicants. However, they are potentially more bioaccumulative, and are suspected to persist in soils and sediments. As they are structurally similar to DEHP and are used in high production volumes for soft PVCs, a critical distribution in the environment can be expected. The structural similarities may cause toxicological effects in humans and environment (UBA 2007). Thus, the following examples concentrate on possible alternatives which are not phthalates.

Citrates (especially O-acetyl tributyl citrate (ATBC), CAS-No. 77-90-7) are esters of citric acid and are used as softeners in PVC products, for printing inks and as softeners for plastic in concrete (COWI 2001). They are being used for cling-films and for toys for babies and toddlers. Their main advantage is that they are biodegradable and not toxic, and can be derived from renewable primary products. Their disadvantage is the considerably higher cost as compared to phthalates.

Hexamoll®DINCH (Di-(isononyl)-cyclohexan-1,2-dicarboxylate, CAS-No. 166412-78-8) is mainly used for the production of toys, medical products, and other PVC products (Biedermann-Brem et al. 2008). Its technical properties are very similar to that of DEHP (Bis(2-ethylhexyl)phthalate). It has been approved by EFSA under corrigendum 2007/19/EG (4th amendment to directive 2002/72/EG) for its use in plastic materials and articles intended to come into contact with foodstuffs. As it was recently notified as a new substance, sufficient data on toxicity and ecotoxicity should be available (UBA 2003, UBA 2007).

Adipates (particularly bis-(2-ethylhexyl)adipate (DEHA), CAS No. 103-23-1 and diisononyladipate (DINA), CAS No. 33703-08-1) are diesters of aliphatic dicarboxylic acids and are produced with varying alcohol groups. They are classified as low temperature plasticizers, and the compounds are relatively sensitive to water (COWI 2001). They are mostly used in PVC, but also in fillers, in paints and lacquers, adhesives, plastic in concrete, and rubber products. DEHA is mostly used in packaging for foodstuffs, DINA mostly for floor covering and wallpapers (UBA 2007).

Phosphates (e.g. di(2-ethylhexyl)phosphate, CAS No. 298-07-7, tri(2-ethylhexyl)phosphate, CAS No. 78-42-2) are triesters of phosphoric acid and includes triaryl and trialkylesters. This group of plasticizers is more resistant to ignition and burning than all the other groups of ester plasticizers and is most often used as flame-retardants in products with specific fire resistant demands. The main uses are in PVC-products used in e.g. the hospital sector, packing, cables, profiles and floor and wall coverings. Tri(2-ethylhexyl)phosphate was not mutagenic and was not found genotoxic in chromosome aberration test and micronuclei assays. Slight evidence of carcinogenicity was observed in mouse, but it has been concluded that the substance is not likely to cause cancer in humans. No data were found on reprotoxicity, embryo toxicity and teratogenicity. There is no data to determine reproductive toxicity or teratogenicity for Di(2-ethylhexyl)phosphate (COWI 2001).

Trimellitates (tri-2-ethylhexyl trimellitate, CAS No. 3319-31-1), pyromellitates and other polycarboxylic acid esters are used for heat resistant plasticized PVC articles due to their exceptional thermal properties. Trimellitates are similar to phthalates with respect to their compatibility and plasticizing effect. They generally have a higher molecular weight and corresponding lower vapour pressure, resulting in a lower migration potential to aqueous solutions compared to phthalates and other plasticizer (COWI 2001).

Alkylsulphonic acid esters (o-toluene sulphonamide (OTSA), CAS No. 88-19-7) are based on phenol, sulphate and an alkyl chain. The sulfonic esters are more resistant with respect to hydrolysis than other ester based plasticizers (COWI 2001). They can be used for PVC exposed to severe weather conditions or strong disinfectants and agents, as well as for toys (UBA 2003). O-toluene sulphonamide is reported as teratogenic in rats, but no detailed description of the study design is available. Only weak mutagenic activity is shown. There is limited evidence that OTSA is carcinogenic when administered orally to rats. This has been suggested as the cause of carcinogenicity of saccharin. The available data suggest that OTSA impurities at the levels normally found in commercial saccharin do not contribute to the carcinogenicity of saccharin. Based on very limited data the critical effect has been identified as possible teratogenicity (COWI 2001).

Butane esters (2,2,4-trimethyl-1,3-pentanediole diisobutyrate (TXIB), CAS No. 6846-50-0) is mostly used in PVC-products e.g. in the hospital sector, packaging, cables, profiles, floor and wall coverings, printing ink and paint/lacquer (COWI 2001).

Polyesters (polyadipates) are medium viscous polymeric softeners derived from adipic acid, used for oil and grease resistant uses of PVC, and can be used for the production of packaging foil and floor coverings. They comply with several food law requirements.

Epoxyester and epoxydised oils, of which epoxidised soybean oil (ESBO, CAS No. 8013-07-8), which is produced by epoxidation of soybean oil is the dominant plasticizer. ESBO has a high molecular weight and a spacious molecular structure, which makes it more resistant to migration (COWI 2001).

Benzoates (Dipropylene glycol dibenzoate, CAS No. 27138-31-4) may be mainly used in adhesives and fillers (COWI 2001).

Sebacates (Dioctyl sebacate (DOS), CAS No. 122-62-3) are used to add good low temperature flexibility, and generally have the same plasticizing properties as adipates and azilates (COWI 2001).

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).

Alternative polymeric materials

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 in the long term the use of plastics that show elastic properties without addition of plasticizers namely polyethylene or polypropylene (UBA 2003; UBA 2007).

UBA (2003) gives an overview on options to substitute phthalates as plasticizers in plastics: For the alternatives, information is given on i) technical suitability, and costs ii) existing applications in products and by companies and iii) environmental and health related advantages and disadvantages.

The main application of phthalates in EEE is their use in PVC cables. For cables, there are PVC-free materials available (c.f. Section 4.4).

References

- Austria (2008a): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: benzyl butyl phthalate.
- Austria (2008b): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: dibutyl phthalate.
- Biedermann-Brem S., Biedermann M., Pfenninger S., Bauer M., Altkofer W., Rieger K., Hauri U., Droz C., Grob K. (2008): Plasticizers in PVC Toys and Childcare Products: What Succeeds the Phthalates? Market Survey 2007, Chromatographia (2008), accepted
- 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
- TNO – Netherlands Organisation for Applied Scientific Research (2001): Alternatives for phthalates. TNO-Report STB-01-55, Delft.
- UBA – Umweltbundesamt (1999): Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC. Erich Schmidt Verlag, Berlin
- UBA – Umweltbundesamt (2001c): Erarbeitung von Maßnahmenvorschlägen zur Substitution umweltrelevanter Flammschutzmittel bei Leiterplatten, Außengehäusen für IT- und TV-Geräte sowie Polyurethan-Dämm- und Montageschäumen. Workshop-Berichte.
- UBA – Umweltbundesamt (2003a): Guidance for the use of environmentally sound substances, Part 5.1: Plasticizers
- UBA – Umweltbundesamt (2007): Phthalate – Die nützlichen Weichmacher mit unerwünschten Eigenschaften. http://www.umweltbundesamt.de/uba-info-presse/hintergrund/weichmacher.pdf

4.3 Nonylphenol[69] and nonylphenol ethoxylates

In many application areas the use of nonylphenol and nonylphenol ethoxylates has already been phased out as a result of the restrictions specified in Directive 76/769/EEC and item 46 of Annex XVII to REACH. The known remaining applications are the use as solubilizer in tin electrolytes for printed wiring boards and in curing systems for epoxy resins. End use applications include high temperature resistant module potting, current transformer potting, electrically conductive adhesives and general purpose potting compounds.

Information on possible substitutes has not been made available by the electronic industry in the course of the study. Since nonylphenol and nonylphenol ethoxylates have already been replaced in many application areas (see UBA, 2003), it is, however, reasonable to assume that for the remaining small-volume applications in EEE substitutes are available.

A substitution of nonylphenol / nonylphenol ethoxylates by octylphenol / octylphenol ethoxylates is not recommended. Octylphenol itself is included on the OSPAR list of Chemicals for Priority Action. Octylphenol is very toxic to aquatic organisms, is not easily degraded in the environment, has the potential to cause significant endocrine disruption effects and has been detected in surface waters (OSPAR Commission, 2003).

4.4 Polyvinyl chloride (PVC) and other chlorine containing plastics

PVC is one of the major plastics used in EEE. It is mainly used as insulation and sheathing in wires and cables. Alternatives are available on the market for the vast majority of PVC uses.

For cables, there are PVC-free materials made of PE (Polyethylene) or EVA (Ethyl-Vinylacetate-Copolymere) available that are technically suited for different voltages but more expensive then PVC cables (UBA, 1999). A more expensive but commonly used PVC wire insulation substitute is FEP (fluoroethylene polymer).

The alternative cable types have better properties than PVC in the event of a fire: They generate less smoke, do not release hydrochloric acid or dioxins and have fire-resistant qualities that match or outstrip PVC. All PVC-free cables cost more at present but will drop in price as consumers and municipalities demand safer material use. Use of PVC free electrical cables is growing, particularly in the transportation sector, where safety is critical.

Many underground railway systems in the US and Europe use PVC free cables (also known as low-smoke, zero-halogen or LSOH cables). Vienna, Berlin, Düsseldorf, Bilbao and London all avoid PVC cables underground. Similarly, Eurotunnel, Deutsche Bahn, P&O Cruises and the US Navy all specify PVC free cables.

---

[69] 4-nonylphenol (branched) and nonylphenol

Electrical cables manufacturers have already developed and marketed several halogen-free alternatives to PVC cable, as a result of concern over PVC combustion emissions.

The main alternative power cables, in the high and medium voltage range, use polyethylene as an insulation and sheathing material. Rubber sheathed cables are also available. For low voltage uses such as domestic wiring, the alternatives are polyethylene or rubber insulated halogen free cables.

Polyethylene (PE) is also one of the main substitutes for electrical conduits such as optical fiber and computer network cables (Ackerman and Massey, 2003). Several manufacturers use polyolefin in electrical cords, output cords on AC adapters and power cables. The most important polyolefins are PE, and polypropylene (PP).

Alternatives of insulating and sheathing cables for power circuit lines are low density polyethylenes (LDPE), cross-linked polyethylene (VPE), ethylene-propylen-rubber and fluoric plastics, for energy cables thermoplastic elastomer, LDPE, VPE and PP, for telecommunication cables FRNC, PP, PE. All these substitutes involve no technical disadvantages regarding fire protection because non halogen flame retardants can be added For PE aluminium hydroxide or magnesium hydroxide is used as a flame retardant (UBA, 1999).

In a study of substitutes for soft PVC in toys and children articles, polyolefins, ethylene vinyl acetate, SBS block copolymers and polyester elastomers are sometimes used as substitutes (Postle et al., 2000).

References

- Ackerman, F., and Massey, R., (2003): The Economics of Phasing out PVC, Global Development and Environment Institute (GDAE), Tufts University.
- Postle, M., Cordon, C., van den Berg, M., and Sanderson, T., (2000): The Availability of Substitutes for Soft PVC Containing Phthalates in Certain Toys and Children Articles, Risk & Policy Analysts Limited, Research Institute for Toxicology, final report prepared for European Commission.
- UBA (1999), Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC, Erich Schmidt Verlag, Berlin.

5 Selection of candidates for potential inclusion in RoHS

Under consideration of the selection criteria specified in Section 2.2 so called high priority substances have been identified (Table 5 and Table 6). These substances have further been evaluated by analysis of available risk assessment reports and other relevant information (see Section 3). Special attention was laid, where possible from the available information, on the exposure of environment and human health to the hazardous substances and their degradation/reaction products during the use phase and the recycling/disposal phase of electrical and electronic equipment. For some of the high priority 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 (measured concentrations of hazardous substances in humans, biota and environmental media such as water and sediment) were evaluated and taken into consideration for the proposal of candidate substances. This was done because the detection of substances in humans/biota and environmental compartments is an indication of bioaccumulation and persistence of a substance. Substances identified in humans and biota raise concern regarding potential long-term harmful effects and, if detected in remote areas, regarding long-range transport. Findings of a substance in top predators furthermore indicate a bioaccumulation in the food chain. Effects of such an accumulation in humans/biota and environmental compartments are unpredictable in the long-term and such accumulation is practically difficult to reverse.

Risk management measures must minimise exposures and emissions to humans and the environment that result from manufacture or uses throughout the lifecycle including the waste stage of these substances. In order to reduce the exposure of humans and the environment to these substances as far as possible, these substances should therefore be replaced by less hazardous substances wherever it is possible.

Further to the exposure situation, including the way the substances are entering the environment from the disposal phase, the relevance of EEE with regard to the total consumption of the substances has been taken into account, but quantitative data or ratios of consumption by EEE sector compared to the general consumption figures are clearly lacking for several potential candidate substances.

In a next step the availability of technical suitable and less harmful substitutes and/or alternative technologies has been evaluated. Although for most of the applications under consideration technical viable substitutes exist on the market, it emerged that for most of these substitutes comprehensive risk assessments do not yet exist. In specific cases, further data and investigations are thus necessary before being able to give a full assessment on the adverse effects of substitutes.

Based on the results of this overall analysis, candidate substances for potential inclusion in RoHS are proposed (Table 28). These substances constitute significant health and environmental risks when used in electrical and electronic equipment.

Some of the investigated hazardous substances are only used in small quantities in EEE or by a very limited number of manufacturers, namely MCCPs, SCCPs and nonylphenol/ nonylphenol ethoxylates (Table 29). From toxicological and environmental points of view these substances should be phased-out from EEE, even more so because safer, less harmful substitutes are available for most of the applications. Nevertheless, an inclusion into the RoHS Directive is not recommended for these substances: Due to their limited applications and/or small quantities used in EEE, the costs arising from a restriction of these substances are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. These substances constitute a certain health and environmental risk when used in EEE, but these risks are not considered to be significant due to the limited quantity of these substances used in EEE. A restriction of these substances by their inclusion into the RoHS Directive is considered to be disproportionate. Industry is urged to phase-out these substances from the remaining few applications voluntarily by substitution with safer, less harmful alternatives. Furthermore, the inclusion of these substances in market surveillance programmes is recommended in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase.

Chlorine containing plastics (such as PVC) and other organobromine/organochlorine compounds involve risks associated with their production, processing and especially with their disposal and incineration. The crucial potential for danger lies in the emissions of substances such as organic chlorine compounds and the associated emissions of dioxins and furans. The substances themselves do not meet the classification as dangerous in accordance with Directive 67/548/EEC and thus, they are beyond the terms of reference set for the present study. However, the terms of reference prescribe also that based on extensive review of existing literature and data bases, indications should be examined about the risks for environment and human health arising from the use of the identified hazardous substances in EEE at the various stages of the life cycle of the product - production, use, and, particular end of life management of the equipment in which the hazardous substances are contained.

Evaluation of available data on the group of organobromine and organochlorine compounds revealed that there are risks for environment and human health arising from the use of these substances in EEE, especially during the end-of life stage of the equipment in which they are contained. Therefore, PVC as well as the group of organobromine and organochlorine substances has been considered in the present study and their phase out from EEE is highly recommended by the authors of this study (Table 30).

Arguments both in favour of and against a possible inclusion of the candidate substances into RoHS and the recommended phase out of the other hazardous substances are discussed below.

The following substances that were included in the list of high-priority substances (Table 5) are not proposed as candidate or phase out substances because after evaluation of all available data and information these substances do not clearly fulfil the defined selection criteria as described in Section 2.2 and/or they are not present in the final product in their original chemical form due to reaction with the matrix and/or there is a low risk of exposure to human and environment and/or there is not yet sufficient information on possible exposure and effects available to give a justified recommendation on an inclusion in the RoHS Directive. For details please refer to the partial conclusions on each substance in Chapter 3:

- Beryllium metal; Beryllium oxide (BeO)[70]
- Antimony trioxide
- Bisphenol A (4,4'-Isopropylidendiphenol)
- Diarsenic trioxide; arsenic trioxide
- Dinickel trioxide

---

[70] Beryllium metal and beryllium oxide is not proposed to be restricted by inclusion in RoHS, however, the presence of beryllium containing parts in EEE above a certain concentration level should be labelled in order to ensure that these parts are dismantled and recycled adequately (cf. Section 6.2.2).

Table 28 Candidates proposed for a potential inclusion in RoHS

Substance name	CAS-No.	Classification in accordance with Directive 67/548/EEE	Arguments in favour of inclusion into RoHS	Arguments against inclusion into RoHS
Tetrabromobisphenol A (TBBP-A)	79-94-7	Proposed classification (on 31st ATP): N; R50-53	– Persistent (P) or potentially very persistent (vP), bioaccumulating[71] and toxic for aquatic organisms – Possible degradation in the environment to tetrabromobisphenol-A bis(methyl ether) that possibly meets the screening criteria for a PBT substance – Monitoring data show detections of TBBP-A in biota remote areas. – EU RAR concludes that the use as additive flame retardant may result in risks for the environmental compartments water, sediment and agricultural soil. – Both for the use as reactive and additive FR halogen-free alternatives are available; many producers have stopped using TBBP-A (and the use of brominated flame retardants in general) and point that out in the context of their environmental policy indicating that suitable alternatives are available. – Risk of formation of PBDDs and PBDFs and further hazardous substances	– Based on the available data in the EU RAR, the Risk Reduction Strategy Meeting has come to the conclusion that concerning human health there is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied. – If used as reactive FR, TBBP-A reacts chemically with the polymer and does not maintain any longer its original molecular structure with the consequence that identification and measurement of the concentration of TBBP-A added to the polymer is very difficult and thus, restriction of TBBP-A is difficult to enforce. – Substitutes have not yet been evaluated to the same degree on their toxicological and environmental endpoints – For most possible substitutes no official EU risk assessments are available – Only limited information is available on economic and social impacts of substitution

---

[71] TBBP-A does not fulfil the B or vB criteria as defined by REACH, however, levels of TBBP-A were found in top predators indicating its bioaccumulation potential

Substance name	CAS-No.	Classification in accordance with Directive 67/548/EEE	Arguments in favour of inclusion into RoHS	Arguments against inclusion into RoHS
Hexabromocyclo-dodecane (HBCDD)	25637-99-4	Proposed classification: N; R50-53 with SCL M = 10[72]	– 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 and further hazardous substances	– Proposal to identify HBCDD as SVHC (Annex XV dossier) increases likelihood that HBCDD will be included into REACH Annex XIV and will be subject to authorisation under REACH covering all industry sectors – Substitutes have not yet been evaluated to the same degree on their toxicological and environmental endpoints – For most possible substitutes no official EU risk assessments are available – Only limited information is available on economic and social impacts of substitution

---

[72] Specific Concentration Limits with an M factor 10 (proposed by TC C&L)

Substance name	CAS-No.	Classification in accordance with Directive 67/548/EEE	Arguments in favour of inclusion into RoHS	Arguments against inclusion into RoHS
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	– Substances of very high concern: reprotoxic Cat. 2 and endocrine disruptors Cat. 1 – Water Framework Directive Priority Substance – 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. – Monitoring data indicate an ubiquitous presence of DEHP, BBP and DBP in biota and environmental compartments – Non-phthalate plasticizers and alternatives to PVC are available	– Proposal to identify DEHP, BBP and DBP as SVHC (Annex XV dossier) increases likelihood that they will be included into REACH Annex XIV and will be subject to authorisation under REACH covering all industry sectors – Substitutes have not yet been evaluated to the same degree on their toxicological and environmental endpoints – For most possible substitutes no official EU risk assessments are available – Only limited information is available on economic and social impacts of substitution
Butylbenzylphthalate (BBP)	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53		
Dibutylphthalate (DBP)	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50		

Table 29 Hazardous substances in EEE proposed for voluntary phase out from EEE by industry

Substance name	CAS-No.	Classification in accordance with Directive 67/548/EEE	Arguments in favour of inclusion into RoHS	Arguments against inclusion into RoHS
Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	R64 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	– 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” – 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 – Risk of formation of PBDDs and PBDFs and further hazardous substances	– Only limited number of applications and/or small quantities used in EEE with the consequence that costs arising from restriction are expected to exceed benefits – Only limited information is available on environmental, economic and social impacts of substitution

Substance name	CAS-No.	Classification in accordance with Directive 67/548/EEE	Arguments in favour of inclusion into RoHS	Arguments against inclusion into RoHS
Short-chained chlorinated paraffins (SCCPs) (Alkanes, C10-13, chloro)	85535-84-8	Carc. Cat. 3; R40 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	– Substances of very high concern: endocrine disruptors (Cat. 1) & PBT substances – 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 SCCPs as body burden in biota – Risk of formation of PCDDs and PCDFs and further hazardous substances	– Proposal to identify SCCPs as SVHC (Annex XV dossier) increases likelihood that SCCPs will be included into REACH Annex XIV and will be subject to authorisation under REACH covering all industry sectors – Only limited number of applications and/or small quantities used in EEE with the consequence that costs arising from restriction are expected to exceed benefits – Only limited information is available on environmental, economic and social impacts of substitution
Nonylphenol [1] / 4-nonylphenol, branched [2] Nonylphenol ethoxylates	25154-52-3 [1] / 84852-15-3 [2] 9016-45-9	Repr. Cat. 3; R62-63 Xn; R22; C; R34 N;R50-53 Currently not present in Dir. 67/548/EEC.	– 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	– Only limited number of applications and/or small quantities used in EEE with the consequence that costs arising from restriction are expected to exceed benefits – Only limited information is available on environmental, economic and social impacts of substitution

Table 30 Potentially dangerous substances (not meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC), recommended to be phased out from EEE

Substance name	**CAS-No.**	**Classification in accordance with Directive 67/548/EEE**	**Arguments in favour of inclusion into RoHS**	**Arguments against inclusion into RoHS**
Organobromine and organochlorine compounds	Substance-specific	Substance-specific	– Risk of formation of brominated/chlorinated dioxins and furans and further hazardous substances. – Br and Cl free alternatives are available and already used by manufacturer of EEE	– Large group of compounds with different hazard potential; in-depth evaluation of each single compound was beyond the scope of the present study
PVC	9002-86-2	Not classified as hazardous	– PVC material used in EEE contains a number of hazardous additives (e.g. phthalates) – Risk of formation of brominated/chlorinated dioxins and furans and further hazardous substances – PVC free alternatives are available and already used by manufacturer of EEE	– PVC itself is not classified as dangerous in accordance with Directive 67/548/EEC; hazardous additives are treated separately in the present study

5.1 Discussion of proposed candidate substances

5.1.1 TBBP-A

TBBP-A is considered to be persistent (P) or potentially very persistent (vP), and though it does not fulfil the criteria for bioaccumulation it does have a certain potential to bioaccumulate indicated by various monitoring data. Furthermore, TBBP-A is toxic to aquatic organisms. The possible effects of TBBP-A on the endocrine system are subject to current research in the EU FIRE project[73].

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 Faroe 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. EU Risk reduction strategies did not identify at this stage any need for further risk mitigation measures. In case of uncontrolled fires (accidental fire) and upon co-combustion at lower temperatures or in 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. The residues are mostly disposed on uncontrolled dump sites, which are set on fire regularly (Section 2.6).

For the use as additive flame retardant in ABC sufficient halogen-free alternatives are available on the market (Section 4.1.1). Although (eco-) toxicity data for the potential substitutes are incomplete and for the majority no comprehensive risk assessments are available, obtainable literature data suggest that alternatives exist which pose less risk to human health and the environment.

---

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

A phase-out of additive TBBP-A would, thus, be possible at a rather short notice.

For the use as reactive flame retardant in epoxy and polycarbonate resins marketable halogen-free alternatives are available, too. A medium-term phase out of reactive TBBP-A is therefore considered to be possible. Many producers have already stopped using TBBP-A (as well as brominated flame retardants in general) and point that out in the context of their environmental policy.

It is noted, however, that reactive TBBP-A has reacted with the polymer and does not maintain any longer its original molecular structure with the consequence that identification and quantification of reactive TBBP-A is very difficult. Thus, restriction of reactive TBBP-A will be complex to enforce.

Only limited information has been available on environmental (e.g. energy use, toxicity, impact on waste stream), social (occupational health and consumer safety) and economic impacts emerging from a phase out and substitution of TBBP-A. No information has been provided by the electronic industry which costs would arise through a restriction TBBP-A in the supply chain both for industry and consumers. Furthermore, no information was provided on the question which advantages/disadvantages a restriction of TBBP-A would have on the competitiveness of industry on the internal and external market. A comprehensive impact assessment has therefore not been possible.

Overall, the authors of the study consider that the phase out of TBBP-A from EEE should have priority over selective risk management measures to guarantee a reduced emission of TBBP-A during all stages of the life cycle. It is concluded that there are technically suitable, less harmful alternatives available, both for the use as active and reactive flame retardant. Therefore, a restriction of the use of TBBP-A in EEE by appropriate policy options is recommended by the authors of the study.

5.1.2 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. In accordance with REACH, ECHA has published an Annex XV dossier for HBCDD prepared by Sweden with the proposal to identify HBCDD as a PBT substance and thus as SVHC.

Available monitoring studies prove that HBCDD levels are found in biota in remote areas e.g. in marine mammals like seal and porpoise, in marine birds' eggs as well as in freshwater fish and terrestrial birds. These findings suggest that HBCDD undergoes long-range atmospheric transport, accumulates in biota and biomagnifies in the marine and aquatic food web.

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.

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 4.1.2); thus a phase-out of HBCDD would be possible at a rather short notice.

As it was the case with TBBP-A, only limited information has been available on environmental (e.g. energy use, toxicity, impact on waste stream), social (occupational health and consumer safety) and economic impacts emerging from a phase out and substitution of HBCDD. A comprehensive impact assessment has therefore not been possible.

Overall, the authors of the study consider that the phase out of HBCDD from EEE should have priority over selective risk management measures to guarantee a reduced emission of HBCDD during all stages of the life cycle. It is concluded that there are technically suitable, less harmful alternatives available for HBCDD. Therefore, a restriction of the use of HBCDD in EEE by means of appropriate policy options is recommended by the authors of the study.

The necessity to limit the risk for the environment and for humans via the environment has also been identified in the EU RAR and in the RRS Meeting. However, although HBCDD is proposed to be identified as SVHC under REACH, it is not sure yet whether HBCDD will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent HBCDD will be regulated under REACH.

5.1.3 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. In accordance with REACH, ECHA has published Annex XV dossiers for DEHP, BBP and DBP, respectively, with the proposal to identify them as CMR Cat. 2 substances and thus as SVHC.

Phthalates are mainly used as plasticizers (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 29 000 tonnes in 2007. Consumption figures concerning the amount of DBP and BBP used in electronic applications are not available; however, stakeholders from the electronic industry confirmed that DBP and BBP are used as plasticizers in their products e.g. in connector wires.

Monitoring data in the aquatic compartment show that DEHP is ubiquitously found in environmental compartments including biota. 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 plasticizers are available e.g. adipates, citrates, (organo)phosphates and trimelliate (Section 4.2). Several of the alternative plasticizers do show advantages from an environmental point of view compared to phthalates. Another possibility is the use of plastics like polyethylene or polypropylene that show elastic properties without the addition of plasticizers. The main application of phthalates in EEE is their use in PVC cables. For cables, PVC-free polymer materials are available.

As it was the case with TBBP-A, only limited information has been available on environmental (e.g. energy use, toxicity, impact on waste stream), social (occupational health and consumer safety) and economic impacts emerging from a phase out and substitution of DEHP, BBP and DBP. A comprehensive impact assessment has therefore not been possible.

Overall, the authors of the study consider that the phase out of DEHP, BBP and DBP from EEE should have priority over selective risk management measures to guarantee a reduced emission of these three phthalates. It is concluded that there are technically suitable, less harmful alternatives available. Therefore, a restriction of the use of DEHP, BBP and DBP in EEE by means of appropriate policy options is recommended by the authors of the study.

Although DEHP, BBP and DBP are proposed to be identified as SVHC under REACH, it is not sure yet whether they will be included in Annex XIV to REACH (i.e. the list of substances subject to authorisation). Consequently it is not sure yet to what extent DEHP, BBP and DBP will be regulated under REACH.

5.1.4 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.

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 plasticizers / 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. Information received during a stakeholder consultation indicates that MCCPs are only used in small quantities in EEE or by a very limited number of manufacturers.

Since MCCPs are not generally reacted or 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. 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.

It can be summarised that because of their persistent, bioaccumulating and toxic properties and because of their potential to form hazardous reaction products, these substances should be phased-out from EEE, even more so because safer, less toxic substitutes are available for most of the applications. Nevertheless, an inclusion into the RoHS Directive is not recommended for these substances: Due to their limited applications and/or small quantities used in EEE, the costs arising from a restriction of these substances are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. These substances constitute a certain health and environmental risk when used in EEE, but these risks are not considered to be significant due to the limited amount of these substances used in EEE. A restriction of these substances by their inclusion into the RoHS Directive is considered to be disproportionate. However, industry is urged to phase-out these substances from the remaining few applications voluntarily by substitution with safer, less toxic alternatives. Furthermore, the inclusion of these substances in market surveillance programmes is recommended by the authors in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase.

5.1.5 Short-chained chlorinated paraffins SCCPs

The electronic industry states that short-chained chlorinated paraffins (SCCPs) are not any longer in common use in EEE. SCCPs were mainly used in the production process of EEE e.g. for metal working like molding, etc. The use of SCCPs in metal working has meanwhile been restricted by Council Directive 76/769/EC and by REACH Annex XVII (item 27).

Only one manufacturer confirmed the continued use of SCCPs both as flame retardant in power supplies (as part of medical and military component assemblies) as well as plasticizer in connector wires. Thus it can be concluded that SCCPs are only used by a very limited number of manufacturers. The overall quantity of SCCPs used in EEE is therefore assumed to be quite low.

SCCPs are persistent, bioaccumulative and toxic substances fulfilling all PBT criteria. ECHA has published an Annex XV dossier for SCCPs prepared by the UK with the proposal to identify SCCPs as PBT substances and thus as SVHC.

SCCPs are included in the priority list of Hazardous Substance of the European Water Framework Directive and meet the screening criteria for consideration as candidate persistent organic pollutants (POP[74]) under international conventions.

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.

As already outlined for MCCPs, the uncontrolled incineration of chlorinated paraffins may result in the formation of polychlorinated dioxins and furans and other hazardous substances (see respective paragraph of Section 5.1.4).

Due to the limited applications and/or small quantities of SCCPs used in EEE, their inclusion into the RoHS Directive is not recommended even though they fulfil the PBT criteria and therefore should be phased-out from EEE. The costs arising from a restriction of these substances by an inclusion in the RoHS Directive are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. However,

---

[74] 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.

industry is urged to phase-out these substances from the remaining few applications voluntarily by substitution with safer, less toxic alternatives. Furthermore, the inclusion of these substances in market surveillance programmes is recommended in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase, at least until a possible regulation under REACH takes hold.

5.1.6 Nonylphenol[75] and nonylphenol ethoxylates

The electronic industry states that nonylphenol and nonylphenol ethoxylates are not any longer used in electrical equipment as most of the historic uses have been phased out since January 2005 by the restrictions 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 stakeholder claimed that nonylphenol ethoxylates are still used as solubilizer in tin electrolytes for printed wiring boards. In this application nonylphenol ethoxylates are used as process chemicals that have the function to reduce the surface tension of tin electrolytes. As process chemicals nonylphenol ethoxylates are not present in the final products. The timeline for the phase-out of nonylphenol ethoxylates from this application is set to the end of 2008 by the respective stakeholder.

The use of nonylphenol ethoxylates in curing systems for epoxy resins has been confirmed by another stakeholder. Some of the end use applications include high temperature resistant module potting, current transformer potting, electrically conductive adhesives and general purpose potting compounds. Thus it can be concluded that nonylphenol ethoxylates are only used by a very limited number of manufacturers. The overall quantity of nonylphenol ethoxylates used in EEE is therefore assumed to be quite low.

---

[75] 4-nonylphenol (branched) and nonylphenol.

Due to the limited applications and/or small quantities of nonylphenol and nonylphenol ethoxylates used in EEE, their inclusion into the RoHS Directive is not recommended even though from a toxicological point of view these substances should be phased-out from EEE. The costs arising from a restriction of these substances by an inclusion in the RoHS Directive are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. However, industry is urged to phase-out these substances from the remaining few applications voluntarily by substitution with safer, less toxic alternatives. Furthermore, the inclusion of these substances in market surveillance programmes is recommended in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase.

5.1.7 Organobromine and organochlorine compounds

Brominated and chlorinated substances as listed Table 21 have the potential to form polybrominated and polychlorinated dioxins and furans in case of uncontrolled fires (accidental fire) and upon co-combustion at lower temperatures or in not well functioning incinerators. This is of specific importance for EEE because presence of copper in EEE catalysis these formation processes. Even after a phase-out of polybrominated biphenyls, high levels of halogenated dioxins and furans are found in European WEEE, probably due to the use of other brominated and chlorinated halogenated flame retardants (Schlummer et al. 2007).

Only by the application of advanced disposal technologies the formation of dioxins and furans and further hazardous combustion products can be avoided. This includes sufficiently high temperatures for thermal degradation as well an effective flue gas cleaning. A large amount of used electrical and electronic equipment is exported for refurbishment and reuse to African and Asian destinations. Here recovering of plastics and metals often takes place without sufficient emission reduction measures, e.g. by open burning of WEEE and uncontrolled dumping of the residues. Several recent studies show contamination of the environment and increased body burdens of humans at places of intensive electronic recycling in developing countries. Uncontrolled processing of EEE resulted in a manifold exceeding of acceptable daily intake values von dioxins and furans. Additionally, also other halogenated persistent substances have been found in these places in highly elevated concentrations.

Under these circumstances, it is not sufficient to define selective risk management measures, e.g. in form of controlled waste disposal, because they are not applied for larger amounts of WEEE. Only by reduction of the content of organobromine and organochlorine compounds the hazardous potential of these waste fractions and further contaminations can be reduced.

For these reasons, the group of organobromine and organochlorine substances have been considered in the present study and their phase out from EEE is highly recommended by the authors.

5.1.8 PVC

As mentioned in Section 3.16, it has not been possible to make a further evaluation of all organochlorine compounds in the framework of this study. Priority has therefore been given to PVC for which it is known that it is used in high amounts in electrical and electronic compounds.

PVC itself is not classified as dangerous according to Directive 67/548/EEC; however, the substances involved in producing PVC are classified as carcinogenic category 1 (vinyl chloride monomer), as carcinogenic category 2 (ethylene dichloride) and as corrosive and irritant to the respiratory system (hydrogen chloride). Furthermore, PVC contains several additives that are classified as substances of very high concern (e.g. phthalates like DEHP, chlorinated paraffins as MCCPs, etc.).

The production of PVC plastic uses the largest proportion of chlorine produced (30%) and is a major source of hazardous substances in the environment, both during manufacture and disposal. As well as using chlorine as a raw material, PVC contains many additives, some of which are also hazardous, such as phthalate or chlorinated paraffins (see above).

In Europe, where emission control technology is available for incinerators, emission of hazardous substances formed during incineration of PVC is normally reduced to acceptable levels. If used and obsolete EEE containing PVC plastic is, however, shipped for refurbishment and reuse to African and Asian destinations where recycling and disposal practices take place without European environmental and work-safety standards, incineration of PVC plastic often results in the emission of toxic substances such as dioxins. But incineration of PVC is not just a problem because of dioxin emissions. Burning PVC also produces a large number of by-products of combustion, including carcinogens such as vinyl chloride, polychlorinated biphenyls (PCBs), chlorobenzene and other aromatic hydrocarbons such as benzene, toluene, xylene, and naphthalene. In addition, large amounts of solid wastes such as slag, ash, filter residues and neutralisation salt residues are produced.

Due to new technologies in recycling processes developed by the European PVC industry, PVC recycling rates are continuously increasing. Nevertheless, recycling rates are still low compared to landfilling and incineration. According to PE Europe et al. (2004) PVC recycling rates for post consumer waste in Europe represented only 3%, whereas 82% of PVC post-consumer waste was landfilled, and 15% was incinerated (in the year 2000).

Due to its durability PVC has a long lifetime and does not decompose readily or quickly. PVC additives such as phthalates do eventually leach when PVC is landfilled, thus posing a risk to groundwater.

For these reasons, PVC has been considered in the present study despite the fact that it is a polymer and as such can not be classified as dangerous in accordance with Directive 67/548/EEC. This polymer is thus not triggering any further review according to the terms of reference of this study. The phase out of PVC should however according to the authors have priority over selective risk management measures to guarantee a reduced release of PVC, of its additives and of hazardous combustion products.

6 Policy options

6.1 Overview on possible policy options

DG Environment elaborated 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 31.

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 others do acknowledge that RoHS could be used as the legal instrument, if risk and economic assessments would justify such a 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 clearly support 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, though, 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 31 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 stakeholders;	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 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.

Policy option	Pros / advantages	Cons / disadvantages
(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 risk that the specific use of the given HS presents;	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".
(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.

6.2 Discussion of policy options

6.2.1 Policy option (1): RoHS versus REACH

The potential policy option number (1) outlined in Table 31 proposes to deal with new hazardous substances under REACH and not under RoHS. Against this background, the characteristics of REACH with relevance to RoHS as well as possible interactions between these two regulations are described in this section.

The key question is whether placing the substances under the authorisation of REACH would offer advantages compared to including them in RoHS.

Background

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 mainly their recycling and general waste treatment into account. In a recent study, an overview on relations and potential impacts between RoHS and REACH has been given (ARCADIS ECOLAS and RPA 2007).

REACH replaces several regulations related to chemicals. These regulations are listed in REACH Article 139. The RoHS Directive co-exists in parallel to REACH.

Improvement of data on hazardous properties and on uses of substances

Similar to other regulations dealing with substances, the future development of the RoHS Directive should use new information on substances which will be generated in the course of the implementation of REACH. Data generation takes place during registration of substances. Registration requires data regarding hazardous properties of substances and regarding the use of the substances.

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 by 1 December 2010, for medium production volume chemicals by 1 June 2013, and for low production volume substances by 1 June 2018. The improvement of the data regarding hazardous properties and uses is also expected for substances which can be used as substitutes.

Data on availability of substitutes

Within the registration of a substance under REACH, it is not required to assess the possibilities of substitution of hazardous substances. This is only the case for substances of very high concern which will be listed in Annex XIV. Manufacturers or user applying for authorisation will have to provide information on the availability of substitutes. REACH Article 62.4 specifies the information requested for the application of an authorisation. One element is an analysis of the alternatives considering their risks, and the technical and economic feasibility of substitution. This should include, if appropriate, information about any relevant research and development activities by the applicant (REACH Article 62.4 (e)). Within this requirement, however, it is not necessary that the applicant provides an overview on all possible ways of substitution. He can concentrate on his own activities. Therefore, also in REACH a direct stakeholder involvement is foreseen in order to get a comprehensive knowledge on the availability of substitutes. This is similar to the present procedure under RoHS.

Definition of substances of very high concern

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 in the corresponding Annex XIII of REACH (Annex XIII Criteria).

By contrast, under waste legislation, hazardous substances are those substances that meet the criteria for classification as dangerous in accordance with Directive 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 Directive 67/548/EEC. Therefore, even in the future, hazardous substances under waste legislation will be wider in scope than SVHC under REACH.

In the present report, hazardous substances meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC which are used in electrical and electronic equipment have been identified. In a second step, it has been assessed whether these substances fulfil the criteria of substances of very high concern as defined by REACH.

Though REACH does not limit the possibility of setting restrictions to substances of very high concern, authorisation under REACH is only foreseen for substances of very high concern. Substances which are subject to authorisation will be listed in Annex XIV.

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. The important aspects regarding RoHS can be summarized as follows:

Requirements for substances of very high concern in articles (REACH Article 57)

REACH Article 7.2 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 (covering not nearly all substances with a production volume of 1 ton/year and more[76] in nearly all uses[77], but regulating a limited number of hazardous substances in electrical and electronic equipment).

The concentration limit given in REACH Article 7.2 (0,1% weight by weight) is equal to the concentration limit given in RoHS for lead, mercury, hexavalent chromium, PBB, and PBDE. It is ten times higher than the concentration limit given in RoHS for cadmium (0,01% by weight). At present, it is under discussion whether the concentration limit in REACH should correspond to the whole article under consideration or to homogeneous materials within the articles. In RoHS, the concentration limit refers to the substances in homogenous materials (that cannot be mechanically disjoined into different materials). A reference to the whole article would allow much higher concentrations in specific parts of the article than a reference to the homogenous materials.

Authorisation procedure under REACH

REACH Article 59 describes the specific process for the identification of substances of very high concern (as defined by REACH Article 57) and for the establishment of a candidate list for eventual inclusion in Annex XIV (list of substances subject to authorisation). 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

---

[76] Certain groups of substances are excluded from REACH or from certain titles of REACH (see REACH Article 2)

[77] 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).

European Chemicals Agency on request by the Commission. There is no deadline for the candidate list, but there is the deadline of 1 June 2009 for the Agency to propose a list of priority substances for inclusion in Annex XIV. The candidate list has to be published before this date.

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 point).

For the next step in the authorisation procedure – the selection of substances to be included in Annex XIV – criteria for priority setting are given in REACH Article 58.3. Priority shall normally be given to substances with PBT or vPvB properties / or wide dispersive use / or high production volumes. This recommendation does not reflect the scope of the RoHS Directive which is specifically regulating hazardous substances in electrical and electronic equipment.

At present, it is not known which substances will be on the candidate list and which substances will be listed in Annex XIV. By the end of June 2008 the European Chemicals Agency (ECHA) published a list of substances for which Member State Competent Authorities or ECHA have prepared Annex XV dossiers for the identification of substances of very high concern. Table 32 gives an overview on those substances. The table includes the prioritisation criteria given in REACH Article 58.3 concerning the inclusion of substances into Annex XIV.

Table 32 Relevant parameters regarding the treatment of the selected high priority substances under REACH authorisation

Substance name	**CAS-No.**	**Classification (Dir 67/548/EEC)**	**REACH SVHC**	**Annex XV dossier available**	**Criteria for priority setting according to REACH Art. 58.3**		
					PBT sub-stance	**Wide disperse sue**	**High production volume**
Tetrabromo bisphenol A (TBBP-A)	79-94-7	Proposed classification (on 31st ATP): N; R50-53	No	no	no	yes	yes
Hexabromocyclododecane (HBCDD)	25637-99-4	Proposed classification: N; R50-53 with SCL M = 10[78]	PBT[79]	yes	yes	yes	yes
Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	R64 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	PBT under evaluation (CSTEE[80] concluded it fulfils PBT criteria); ED Cat. 1[81] /	no	likely	yes	yes
Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	Carc. Cat. 3; R40 R66 N; R50-53 (on adopted 30th ATP, to be published soon)	PBT; ED Cat. 1	yes	yes	yes	yes
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Repr. Cat. 2; R60-61	CMR (Repr. Cat. 2) ED Cat. 1	yes	no	yes	yes

---

[78] Specific Concentration Limits with an M factor 10 (proposed by TC C&L)

[79] PBT: persistent and bioaccumulative and toxic substances (EC 2007)

[80] Comité Scientifique de Toxicologie, Ecotoxicologie et l'Environnement (European Scientific Committee on Toxicity, Ecotoxicity and Environment)

[81] Categorisation of the endocrine disrupting activity according to the EU EDS database that was developed within the EU-Strategy for Endocrine Disrupters: http://ec.europa.eu/environment/endocrine/strategy/substances_en.htm#report3

Substance name	**CAS-No.**	**Classification (Dir 67/548/EEC)**	**REACH SVHC**	**Annex XV dossier available**	**Criteria for priority setting according to REACH Art. 58.3**		
					PBT sub-stance	**Wide disperse sue**	**High production volume**
Butylbenzylphthalate (BBP)	85-68-7	Repr. Cat.2; R61 Repr. Cat.3; R62 N; R50-53	CMR (Repr. Cat. 2) ED Cat. 1	Yes	No	Yes	Yes
Dibutylphthalate (DBP)	84-74-2	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	CMR (Repr. Cat. 2) ED Cat. 1	Yes	No	Yes	Yes
Nonylphenol [1] / 4-nonylphenol, branched [2]	25154-52-3 [1] / 84852-15-3 [2]	Repr. Cat. 3; R62-63 Xn; R22; C; R34 N;R50-53	ED Cat. 1	No	No	Yes	Yes
Nonylphenol ethoxylates	9016-45-9	Currently not present in Dir. 67/548/EEC.	ED Cat. 1	No			
Beryllium metal	7440-41-7	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	No	No	Yes	No
Beryllium oxide (BeO)	1304-56-9	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43	CMR (Carc. Cat. 2)	No	No	Yes	No
Antimony trioxide	1309-64-4	Carc Cat. 3, R40	No	No	No	Yes	Yes
Bisphenol A (4,4'-Isopropylidendiphenol)	80-05-7	Repr. Cat. 3; R62 Xi; R37-41 R43 R52 (on adopted 30th ATP, to be published soon)	ED Cat. 1	No	No	Yes	Yes
Diarsenic trioxide; arsenic trioxide	1327-53-3	Carc. Cat. 1; R45 T+; R28; C; 34 N; R50-53	CMR (Carc. Cat. 1)	Yes	Not further assessed in this study		

Substance name	**CAS-No.**	**Classification (Dir 67/548/EEC)**	**REACH SVHC**	**Annex XV dossier available**	**Criteria for priority setting according to REACH Art. 58.3**		
					PBT sub-stance	**Wide disperse sue**	**High production volume**
Dinickel trioxide	1314-06-3	Proposed classification (on 31st ATP): Carc. Cat. 1; R49 T; R48/23 R43 R53	CMR (Carc. Cat. 1)	No	Not further assessed in this study		

As indicated in Table 32, Annex XV dossiers have been prepared (status August 2008) for the following substances assessed in this report (cf. Chapters 3 to 5):

- **HBCDD**: Substance of very high concern, therefore possibly subject to authorisation. HBCDD is classified as PBT, it has wide dispersive uses, and it is produced in high volumes.
- **SCCPs**: Substances of very high concern, therefore possibly subject to authorisation. SCCPs are classified as PBTs, have wide dispersive uses, and are produced in high volumes.
- **DEHP, BBP, DBP**: Substances of very high concern, therefore possibly subject to authorisation. They are not classified as PBT (but as CMR).

The preparation of an Annex XV dossier is an essential requirement for inclusion of a substance into the candidate list. Therefore, it is likely that the above listed substances will be included into the candidate list. The deadline for comments and further information by interested parties was 14 August 2008.

In addition, an Annex XV dossier has been prepared for diarsenic trioxide, which has also been discussed in the present study but has not been further evaluated because of the reasons given in Section 3.15. Diarsenic trioxide is a substance of very high concern and therefore possibly subject to authorisation under REACH.

A complete list of all 16 substances for which Annex XV dossiers have been prepared is published on the ECHA website[82].

For the following individual substances which have been assessed in this study (cf. Chapters 3 to 5) no Annex XV dossiers have been prepared (status August 2008):

- **MCCPs, nonylphenol / nonylphenol ethoxylates, bisphenol-A and dinickel trioxide**[83]: Substances of very high concern. However, they are not classified as PBT (but have endocrine disrupting properties (Cat.1)). Thus, they fulfil only two of the REACH Art. 58.3 criteria for priority setting regarding inclusion into Annex XIV, namely wide dispersive use and high production volume. It is less likely that they will be included in Annex XIV.

---

[82] http://echa.europa.eu/consultations/authorisation/svhc/svhc_cons_en.asp

[83] Bisphenol-A and dinickel trioxide have been discussed in the present study but have not further been evaluated because of the reasons given in Sections 3.13 and 3.14.

- **Beryllium metal and beryllium oxide**: Substances of very high concern. However, they are neither classified as PBT nor high production volume substances. Thus, they fulfil only one of the REACH Article 58.3 criteria for priority setting regarding inclusion in Annex XIV, namely wide dispersive use. It is unlikely that they will be included in Annex XIV. These substances can not be included in the candidate list as long as no Annex XV dossiers are prepared by the Competent Authorities or ECHA (which might be the case in future).
- **TBBP-A and antimony trioxide**[84]: These substances do not fulfil the criteria of REACH Article 57 for substances of very high concern. Therefore, they can not be subject of authorisation.

All high priority hazardous substances listed in Table 5 have to be registered under REACH by the end of November 2010.

In the process of selecting a substance for inclusion in Annex XIV as well as in the process of granting an authorisation, it will be an important aspect whether the substance under consideration is already governed by other regulations. These sector-specific regulations (such as the RoHS Directive) are seen as important pieces of legislation for managing hazardous substances which are not replaced by REACH. As mentioned above, REACH Article 139 describes which regulations are replaced by REACH. If a substance is already restricted or banned under the RoHS Directive, this specific use will not be covered by the REACH authorisation obligations, leaving the RoHS ban intact. In this case the REACH authorisation can cover all other uses of the substance not regulated by RoHS.

Time lines for authorisations of substances under REACH

At present, it is not known when the placing on the market or the use of a given substance will be forbidden by the authorisation process of REACH. By 1 July 2009 ECHA will publish the list of candidate substances. Afterwards, all interested parties will be invited to submit comments within three months after the date of publication (in particular on uses which should be exempted from the authorisation requirement (REACH Article 54)). After evaluation of these comments, a decision will be made whether to include substances in Annex XIV.

For each substance, the date(s) will be specified from when placing on the market and use of the substance shall be prohibited, unless an authorisation is granted. This date is referred to

---

[84] Antimony trioxide has been discussed in the present study but has not further been evaluated because of the reasons given in Section 3.12.

as “the sunset date”. This date will be substance-specific and, where appropriate, should take the production cycle specified for the use of the substance into account.

For each substance, individual dates will be specified at least 18 months before the sunset date(s) by which applications must be submitted if the applicant wishes to continue to use the substance or place it on the market for certain uses after the sunset date(s). These continued uses shall be allowed after the sunset date until a decision on the application for authorisation is made (REACH Art.58 (c)).

The sunset date(s) and the related date(s) for receiving an authorisation application are substance specific. At present, only the date for the first recommendation of substances for inclusion in Annex XIV is known (1 July 2009), the period for commenting (3 months) and the minimum period of 18 months for receiving an application for authorisation related to the sunset date(s) of a substance.

Discussion of policy option 1 for the substances assessed in this report

Substances included in REACH Annex XIV are not allowed to be placed on the market unless an authorisation is granted. Therefore, authorisation may appear to be an efficient tool to phase out hazardous substances. Compared to an inclusion of the substance in RoHS, the advantage of the REACH authorisation approach is that the restriction of substances listed in Annex XIV will not only apply to a certain sector of use (as it is the case with RoHS), but would cover all uses of the substance – apart from uses, for which an authorisation has been granted. However, at present it is not known how the authorisation will be realised in practice.

REACH authorisation applies only to substances of very high concern. From the substances assessed in this report, TBBP-A can not be phased-out by inclusion in Annex XIV because it is no substance of very high concern. Therefore, for TBBP-A, other policy options than regulation under REACH need to be discussed for a phase-out (cf. Section 6.2.2).

As mentioned before, HBDDC, SCCPs, DEHP, BBP and DBP fulfil the criteria for substances of very high concern. Annex XV dossiers have already been prepared for these substances. Thus, it is likely that these substances will be on the REACH candidate list. They may finally be included in Annex XIV. However, for which substances this will actually be the case, is not yet known.

For MCCPs and nonylphenol / nonylphenol ethoxylates Annex XV dossiers have not (yet) been prepared. In the middle-term, it is therefore unlikely that these substances will be listed in Annex XIV. Consequently, other policy options than policy option 1, i.e. authorisation under REACH, should be used for a phase-out of these substances.

It can be summarised that authorisation by REACH instead of inclusion into RoHS may only be a possible policy option for those substances for which Annex XV dossiers already have been prepared, namely HBDDC, SCCP, DEHP, BBP and DBP. Both possibilities (authorisation under REACH / inclusion into RoHS) have advantages and disadvantages. Authorisation by REACH can cover all uses of the substances. However, at present it is not known whether the substances will be listed in Annex XIV at all. It is also not known whether authorisations will be granted for specific uses of these substances.

Inclusion of the substances into RoHS does not cover the use of these substances in other branches. It would give the possibility to directly define the time lines for the phase-out of these substances – at least from EEE.

At present, the possibility 'authorisation under REACH' holds more uncertainties than the option 'inclusion in RoHS'. By inclusion in RoHS, a clear signal regarding the phase-out of the substances is given. This offers more directional reliability for product design decision, which is strongly needed by industry.

Therefore, regulation of the substances HBCDD, SCCPs, DEHP, BBP, and DBP by the RoHS Directive seems to be more appropriate than authorisation under REACH (cf. Section 6.2.2). Likewise, for TBBP-A, MCCPs, and nonylphenol / nonylphenol ethoxylates, a regulation under RoHS is considered more efficient by the authors since these substances will not be subject to authorisation under REACH in the middle-term.

6.2.2 Discussion of policy options (2) to (8)

In the previous section, the potential policy option number (1) has been discussed in detail, coming to the conclusion that the regulation of the selected hazardous substances under RoHS would give the electronic industry more directional reliability than an authorisation under REACH. In the following section, the suitability of the remaining policy options (2) to (8) of Table 31 are discussed for each single hazardous substance. The results are presented in tabular form in Table 33.

Table 33 Discussion of policy options

Policy option	**TBBP-A**	**HBCDD**	**DEHP**	**BBP**	**DBP**	**SCCPs**	**MCCPs**	**Nonlyphenol/ Nonylphenol-ethoxylate**	**Beryllium (metal + oxid)**
(1) Not add any new justified substances under RoHS and deal with them under REACH	No authorisation under REACH because no SVHC (cf. 6.2.1)	Authorisation under REACH holds more uncertainties than inclusion in RoHS (cf. 6.2.1)					In the middle-term it is unlikely that MCCPs and nonylphenol/nonylphenol ethoxylates will be subject to authorisation under REACH (cf. 6.2.1)		In the middle-term it is unlikely that Beryllium will be subject to authorisation under REACH (cf. 6.2.1)
(2) Add new substances but only for certain categories of EEE in the scope of RoHS	Substances may be contained in all WEEE categories. Restriction to certain categories of EEE is therefore not considered to be reasonable.								Mainly contained in WEEE Cat. 3 and 8[85]. However, in these categories further needed because of its functionality. Inclusion in RoHS not recommended.
(3) Add new substances for all EEE, in the scope of RoHS but with exempted applications	**Preferred policy option for TBBP-A** as for the majority of uses alternatives are available. For remaining applications exemptions may be granted.	It is assumed by the authors that for all applications of HBCDD in EEE alternatives are available. No exemptions necessary.	**Preferred policy option for DEHP, BBP and DBP** as for the majority of uses alternatives are available. For remaining applications exemptions may be granted.			Due to the limited applications and/or small quantities used in EEE, inclusion in the scope of RoHS is not recommended.			Beryllium is further needed because of its functionality. Inclusion in RoHS not recommended.

---

[85] WEEE Cat. 3: IT and telecommunications equipment; WEEE Cat. 8: Medical devices

Policy option	TBBP-A	HBCDD	DEHP	BBP	DBP	SCCPs	MCCPs	Nonlyphenol/ Nonylphenol-ethoxylate	Beryllium (metal + oxid)
(4) Add new substances for all EEE without exemptions at a deferred date	For certain applications exemptions may be needed as no suitable alternatives are available.	**Preferred policy option for HBCDD** because it is assumed by the authors that for all applications of HBCDD in EEE alternatives are available. No exemptions necessary.	For certain applications exemptions may be needed as no suitable alternatives are available.			Due to the limited applications and/or small quantities used in EEE, inclusion in the scope of RoHS is not recommended.			Beryllium is further needed because of its functionality. Inclusion in RoHS not recommended.
(5) Add new justified substances under RoHS only if substitutes already available and fully investigated	For the majority of applications substitutes are available. Even if the substitutes are no fully investigated in all aspects, it is assumed by the authors that technically suitable alternatives exist posing less risk to humans and environment than the hazardous substances proposed for inclusion. Furthermore, inclusion in RoHS and/or phase out from EEE, even with exemptions and postponements, spurs efforts and research into the availability and characteristics of possible substitutes, which would otherwise not take place.								Beryllium is further needed because of its functionality. Inclusion in RoHS not recommended.
(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	This option is no expected to result in risk reduction for human and environment.								

Policy option	**TBBP-A**	**HBCDD**	**DEHP**	**BBP**	**DBP**	**SCCPs**	**MCCPs**	**Nonlyphenol/ Nonylphenol-ethoxylate**	**Beryllium (metal + oxid)**
(7) Not add any new substances but introduce labelling requirements (for example certain phthalates for certain Medical Devices)	This option is no expected to result in risk reduction for human and environment since the hazardous substances would still be present in the waste, and many electrical and electronic components containing the hazardous substances cannot (yet) be recycled adequately. Benefit of this policy option is therefore questionable for these hazardous substances.								**Preferred policy option** to support the safe recycling of beryllium-containing EEE.
(8) Not add any new substances but introduce obligation for easy removability of parts containing hazardous substances	This option is not expected to result in risk reduction for human and environment since the hazardous substances would still be present in the waste, and many electrical and electronic components containing the hazardous substances cannot (yet) be recycled adequately. Benefit of this policy option is therefore questionable for these hazardous substances.								Could be a complementing policy option to # (7) above to support the safe recycling of beryllium-containing EEE.

Out of the set of policy options presented in Table 31 and discussed in Table 33, the policy options summarised in Table 34 are considered as most appropriate for the regulation of TBBP-A, HBCDD, DEHP, BBP and DBP.

The recommendations given by the authors should not be interpreted as a political or legal signal that the Commission intends to take a given action.

Table 34 Summary of proposed policy options for candidate substances

Candidate substance	**Proposed policy option and transition period**[86]
TBBP-A	Policy option 3: Add TBBP-A for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended for the phase-out of TBBP-A used as additive flame retardant. A transition period of 36 months is recommended for the phase-out of TBBP-A used as reactive flame retardant.
HBCDD	Policy option 4: Add HBCDD for all EEE in the scope of RoHS without exemptions. A transition period of 24 months is recommended.
DEHP	Policy option 3: Add DEHP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.
BBP	Policy option 3: Add BBP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.
DBP	Policy option 3: Add DBP for all EEE in the scope of RoHS with possible exempted applications. A transition period of 24 months is recommended.

Concerning the recommendations for restrictions on the use of substances made for EEE, two caveats are important:

Firstly, the documented environmental, economic and social data are not complete, in particular for substitutes. For this reason there can be no robust recommendation as to the need to restrict the use of the substances according to the present state of knowledge and the guidelines for impact assessment of the Commission which this study contract must take into account. The recommendations made are therefore largely based on the overall judgement, and experience of Öko-Institut e.V.

---

[86] The transition period is supposed to start after inclusion of any candidate substance in the revised RoHS Directive, i.e. the adoption by the European Parliament and the Council of the European Union of the revised RoHS and its subsequent publication in the Official Journal.

Secondly, the recommendations to restrict the five substances under the RoHS Directive are not in all cases supported by the conclusions of the official EU risk assessments. This shows the complexity of the policy choice to be made, which must be fully reserved to the discussions of the mandated EU policy makers. This applies even more to the choice between regulatory instruments, e.g. RoHS or REACH, in case a regulation is deemed necessary. The recommendations made in this report must only be understood as one input to making policy choices.

With regard to the assessment of environmental, economic, and social impacts which may occur as a consequence of the proposed policy options, the authors of this study draw the following conclusions:

For the majority of applications of the proposed candidate substances in EEE, substitutes and/or alternative technologies exist on the market. Although most of the possible substitutes have not yet been thoroughly evaluated as to their toxicological effects and environmental impacts, as well as to their technical and economical equivalence, available data tend to suggest that available substitutes could be technically viable with being equal or less hazardous to human health and the environment than the proposed candidate substances. However, comprehensive risk assessments do not yet exist for most substitutes therefore the study limits itself to a hazard assessment.

Except for HBCDD it is not out of question that in few certain cases or applications substitution is technically not feasible or may be counterproductive and might lead to negative environmental or health impacts. Therefore, policy option no. 3 is recommended for the proposed candidate substances (except for HBCDD), thus enabling the industry to apply for exemptions for certain applications.

In the context of this study it has been attempted to collect more information on social and economic impacts of substitution triggered by the proposed policy options. Both the stakeholder consultation carried out in the framework of this service contract and the expert workshop held in May 2008 brought questions related to this kind of impacts into focus. Unfortunately, only limited information could be gathered; therefore, it was not possible to draw a complete picture of economic and social impacts. For some aspects, individual evidence could be collected – see Section 4 on substitutes in this report. However, further research is needed, as outlined in Section 7. This lack of information substantiates that policy option 3 is the most appropriate option for the regulation of TBBP-A, DEHA, BBP and DBP, because whenever substitution is technically or scientifically impractical, exemptions from the legal requirement can be requested.

In addition to the proposed policy options for the substances listed in Table 34, further recommendations are given concerning the hazardous substances MCCPs, SCCPs and nonylphenol/nonylphenol ethoxylates. These substances are only used in small quantities in EEE or by a very limited number of manufacturers. Because of their persistent, bioaccumulating and toxic properties, these substances should be phased-out from EEE, even more so because safer, less harmful substitutes are available for most of the applications. Nevertheless, an inclusion into the RoHS Directive is not recommended for these MCCPs, SCCPs and nonylphenol/nonylphenol ethoxylates: Due to their limited applications and/or small quantities used in EEE, the costs arising from a restriction of these substances are expected to exceed the benefits for human health and the environment resulting from their phase-out from EEE. These substances constitute a certain health and environmental risk when used in EEE, but these risks are not considered to be significant due to the limited amount of these substances used in EEE. A restriction of these substances by their inclusion into the RoHS Directive is considered to be disproportionate. Industry is urged to phase-out these substances from the remaining few applications voluntarily by substitution with safer, less toxic alternatives. Furthermore, the inclusion of these substances in market surveillance programmes is recommended in order to monitor their presence in EEE and to ensure that the quantities used in EEE will not increase.

For beryllium and beryllium oxide, the authors propose the following measures to 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.

PVC as well as the group of organobromine and organochlorine substances cannot be proposed as candidate substances for a potential inclusion in RoHS. PVC does not meet the criteria for classification as dangerous in accordance with Directive 67/548/EEC and substances classified in the organobromine and organochlorine list need to be further investigated on a case by case basis. They are thus beyond the terms of reference set for the present study.

7 Need for further research and outlook

This report concludes that substitutes to the proposed candidate and phase-out substances exist and are available on the market for a large number of applications in EEE. This conclusion is mainly based on publicly available data since only limited information on substitutes has been provided by the electronic industry itself. The available literature data suggest that potential adverse environmental and human health effects are lower for the proposed substitutes than for the candidate/phase-out substances. However, comprehensive risk assessments do not exist for most substitutes. Additional tests on technical suitability, (eco-) toxicological and environmental endpoints may be required for single substitutes, and further research work is necessary to say with certainty that the substitutes pose little or no risk to human health and environment and are therefore "safe" for use as alternatives. The latter applies especially to non-phthalate plasticizers. Therefore, a systematic collection of available data on technical suitability, (eco-) toxicological and environmental endpoints of non-phthalate plasticizers, but also on halogen-free flame retardants and chlorine-free plastics should be supported in order to identify relevant data gaps. In a second step, these data gaps should be closed by appropriate research projects.

Several research projects on potential substitutes and alternatives to brominated flame retardants are already being carried out: 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 late 2008. The "iNEMI BFR-Free PCB Project" of the industry consortium iNEMI (International Electronic Manufacturing Initiative) investigates the technical viability of halogen-free printed circuit board materials. The project aims to promote development of standards by establishing materials, manufacturing, assembly, and test guidelines for bromine flame retardant (BFR)-free printed wiring boards based on market segment requirements and technical, commercial, and functional viability.

After finalisation of the cited research projects, the policy options proposed in the present study may need to be adapted considering the knowledge collected in the research projects.

As pointed out in Section 5, substitutes to phthalates, brominated flame retardants, and chlorine-containing plastics are available for large numbers of applications in EEE. For some applications, however, a full substitution is not (yet) possible mainly due to technical reasons. Industry is asked to specify those applications in detail and to give the exact reasons why substitution is not considered possible.

Furthermore, it should be the task of further research to evaluate the exact uses of and possible substitutes to brominated and chlorinated organic compounds used in EEE, other than those discussed in detail within this study.

In the course of the present study, it has been proposed by representatives of the electronic industry that bromine and chlorine should be restricted at an elemental and homogeneous material level, similar to the restrictions on lead, cadmium, and mercury in the RoHS Directive. This proposal requires all homogeneous materials to contain less than 900 ppm bromine and less than 900 ppm (0,09%) chlorine, regardless of the specific compound in which bromine or chlorine is present. A maximum concentration limit of 900 ppm ensures that bromine and chlorine are replaced rather than reduced for the majority of cases, achieving significant environmental gains. The main argument is that it would not be possible to enforce restrictions on specific organobromine and organochlorine compounds due to the lack of substance-specific and expensive analytical test methods (which so far have only been developed for a limited number of halogenated compounds). Furthermore, reactive forms of e.g. brominated flame retardants cannot be detected since their chemical structures change when they are reacted with the base polymer. In contrast, test methods for detecting total bromine and total chlorine content are available; the most prominent one is X-ray fluorescence spectroscopy (XRF).

Against this background, advantages and disadvantages of a restriction of bromine and chlorine in EEE at an elemental and homogeneous material level should be investigated more in depth.

Limited information exists on environmental (e.g. energy use, toxicity, impact on waste stream), social (occupational health and consumer safety), and economic impacts caused by substitution, compared to the ones of the proposed candidates. No information has been provided by the electronic industry on the question which costs will arise through the restriction of the proposed candidate substances in the supply chain, both for industry and consumers. Furthermore, no information was provided on the question which advantages/ disadvantages the restriction of the proposed candidate substances will have on the competitiveness of industry on the internal and external market. Further impacts may arise from administrative burden (i.e. information and verification activities). The available information has not been specific enough to quantify the impacts mentioned above within the present study.

During the stakeholder consultation, only limited information was received by manufacturers on the question in which quantities the hazardous substances are present in the electrical and electronic components. It was a challenge to gather information on the presence of hazardous in EEE at all.

According to the equipment manufacturers, this information is often not provided by the respective suppliers. 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 from the manufacturers.

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. Other available declaration systems (e.g. the so-called Umbrella specifications (Section 2.3.2)), developed by the German Electrical and Electronic Manufacturer’s Association (ZVEI), are, according to personal statements of experts, not internationally accepted.

The suppliers often only confirm a general “RoHS compliance”. 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 Joint Industry Guide (JIG) Level A / B substances and some recyclable metals (e.g. Cu, Au, Mg, Ni, Pd and Ag).

As mentioned in Section 2.3.4, the existing JIG 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 which are regarded as substances of very high concern according to REACH and which are relevant for electrical & electronic equipment. The Draft JIG Phase 2 Document is scheduled for 2008. It is expected that on this basis the knowledge about potentially hazardous substances in EEE will increase considerably.

Based on the better knowledge on the typical content/composition of electrical and electronic components in combination with data collected in the framework of ongoing activities to energy using products (EuP), the provisional inventory set-up in this study could be expanded, allowing a more comprehensive overview on hazardous substances in EEE. The information derived from such an extended inventory could be used to set priorities in market surveillance activities suggested for MCCPs, SCCPs and nonylphenol / nonylphenol ethoxylates.

8 References

Ackerman, F. & Massey, R. (2003): The Economics of Phasing out PVC, Global Development and Environment Institute (GDAE), Tufts University.

Ackerman, F., and Massey, R., (2003): The Economics of Phasing out PVC, Global Development and Environment Institute (GDAE), Tufts University.

Allsopp, M., Santillo, D. & Johnston, P. (2005): Environmental and Human Health Concerns in the Processing of Electrical and Electronic Waste; Greenpeace Research Laboratories Technical note 04/2006.

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).

Austria (2008a): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: benzyl butyl phthalate.

Austria (2008b): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: dibutyl phthalate.

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.

BiBRO (2002): Behandlungs- und Verwertungswege für PVC- Abfälle, Gesamtbericht, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien Retrieved April 11th, 2008, http://www.bmlfuw.gv.at/article/articleview/29648/1/694.

Biedermann-Brem S., Biedermann M., Pfenninger S., Bauer M., Altkofer W., Rieger K., Hauri U., Droz C., Grob K. (2008): Plasticizers in PVC Toys and Childcare Products: What succeeds the Phthalates? Market Survey 2007, Chromatographia (2008), accepted

Blomqvist, P.; Rosell, L.; and Simonson, M. (2004): Emissions form Fires Part I: Fire Retarded and Non-Fire Retarded TV-Sets, Fire Technology, 40, 39-58.

Brian K. Gullett; William P. Linak; Touati, A; J. Wasson, S; Gatica, S; J. King, C, (2007): Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations, J Mater Cycles Waste Manag. 9:69-79.

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.

Bruce, R. M. & Odin, M., (2001): Beryllium and beryllium compounds, United Nations Environment Programme, the International Labour Organization, and the World Health Organization, Geneva.

BSEF (2008): Plastics Consumption by Sector, Retrieved April 8th, 2008, from http://www.bsef.com/recycling/plastic_consumption/.

Buchert, M., Hermann, A., Jenseit, W., Stahl, H. et al. (2007): Verbesserung der Edelmetallkreisläufe: Analyse der Exportströme von Gebraucht-Pkw und –Elektro(nik)geräten am Hamburger Hafen. Öko-Institut, Darmstadt.

C4E – CEFIC, EECA, EICTA, EUROMETAUX (2002): Guidance Document on the Application of Substances under Special Attention in Electric & Electronic – Products, Published in co-operation by CEFIC, EACEM, EECA, EICTA and EUROMETAUX, Version 2.2.

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.

Crusack, P.A., Herr, M.S. & Monk, A.W. (1997): Zinc hydroxystannate as an alternative synergist to antimony trioxide in polyester resins containing halogenated flame retardants, Polymer Degradation and Stability, Vol. 10, 1-2, pp. 229-237.

Darby, L. & Obara, L. (2005): Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. In: Resources, Conservation and Recycling, 44(1): 17-35.

de Boysère, J. (2006): Halogen-free laminates – the technology is there for an emerging market. EIPC Summer Conference, Venice, June 8-9th 2006. http://www.flameretardants-online.com/news/downloads/over_english/2006_06_halogen_free.pdf

de Boysère, J. (2007): Overview of Alternatives to BRF in E&E Applications – Case Study of Printed Wiring Boards. Fa. Clariant. Konferenzbeitrag BFR 2007, 4th International Workshop on Brominated Flame Retardants, Amsterdam, April 24-27th 2007.

de Witt, C. et al. (2006): Levels and trends of brominated flame retardants in the Arctic; Chemosphere 64 (2006) 209-233.

Detter, F.T (2001): Bromorganische Flammschutzmittel – Analytische Anforderungen und thermische Bildung von polybromierten Dibenzo-p-dioxinen und Dibenzofuranen, Dissertation von der Gemeinsamen Naturwissenschaftlichen Fakultät der Technischen Universität Carolo-Wilhelmina zu Braunschweig.

Döring, M. & Diederichs, J. (2007): Halogen-free flame retardants in E&E applications, Forschungszentrum Karlsruhe, Germany.

EC – European Commission (2007): Assessment of PBT substances under EU chemicals regulations; Directorate General JRC JRC, Institute for Health and Consumer Protection, Ispra, 23 March 2007

ECB – European Chemicals Bureau (2007): Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to DecaBDE. http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf.

ECB – European Chemicals Bureau (2007): Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to

DecaBDE. http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf.

ECHA European Chemicals Agency (2008): Guidance for the implementation of REACH: Guidance on information requirements and chemical safety assessment; Chapter R.11: PBT Assessment.

EPA Denmark – Danish Environmental Protection Agency (2006): Health and environmental assessment of alternatives to Deca-BDE in electrical and electronic equipment.

http://www.mst.dk/Udgivelser/Publications/2007/01/978-87-7052-351-6.htm.

EPA USA – United States Environmental Protection Agency (2006): Flame Retardants in Printed Circuit Boards Partnership. Design for Environment. http://www.epa.gov/dfe/pubs/projects/pcb/index.htm.

EPA USA – United States Environmental Protection Agency (2008): Technical factsheet: Beryllium. http://www.epa.gov/OGWDW/dwh/t-ioc/berylliu.html.

EU Commission (2007): The 14th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Control of Risks of Existing Substances (23/24 October 2007); Subject: Draft Recommendation Appendices for Tetrabromobisphenol A (TBBPA); Doc: ES/20c/2007.

EU Commission (2008): The Review of Directive 2002/95/EC (the "RoHS" Directive) of the European Parliament and of the Council on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment; Invitation for comments on options and for information supply; Dec 07–Feb 08; Summary of comments and information received. http://ec.europa.eu/environment/waste/weee/pdf/2nd_consultation_comments.pdf.

EU Commission (2008a): The 15th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Control of Risks of Existing Substances (22/24 April 2008); Subject: Draft Recommendation Appendices for Hexabromocyclododecane (HBCDD); Doc: Doc: ES/25e/2007 Rev.2.

EU Commission (2008b): The 15th Risk Reduction Strategy Meeting of the Member States for the Implementation of Council Regulation (EEC) 793/93 on the Evaluation and Control of Risks of Existing Substances (23/24 April 2008); Subject: Draft Recommendation Appendices for MCCPs; Doc: ES/12f/2007 Rev. 1.

EU Risk Assessment Dibutylphthalate (DBP), Final Report (2003).

EU Risk Assessment Dibutylphthalate (DBP), Final Report (2003).

EU Risk Assessment Report 1,2-Benzenedicarboxylic Acid, Di-C8-10-Branched Alkyl Esters, C9-Rich and Di-“Isononyl” Phthalate (DINP), Final Report, 2003.

EU Risk Assessment Report 1,2-Benzenedicarboxylic Acid, Di-C9-11-Branched Alkyl Esters, C10-Rich and Di-“Isodecyl” Phthalate (DIDP), Final Report, 2003.

EU Risk Assessment Report 2,2’,6,6’-Tetrabromo-4,4’-Isopropylidene Diphenol (Tetrabromobisphenol-A), Final Environmental Draft (2007).

EU Risk Assessment Report 2,2',6,6'-Tetrabromo-4,4'-Isopropylidenediphenol (Tetrabromobisphenol-A or TBBP-A), Part II – Human Health, Final Report (2006).

EU Risk Assessment Report 4,4'-isopropylidenediphenol (bisphenol-A), Final Report (2003).

EU Risk Assessment Report 4-nonylphenol (branched) and nonylphenol, Final Report (2002).

EU Risk Assessment Report Alkanes, C10-13, chloro, Final Report (1999).

EU Risk Assessment Report Alkanes, C10-13, chloro, updated version 2008.

EU Risk Assessment Report Alkanes, C14-17, chloro (MCCP), Part I – Environment Final Report (2005).

EU Risk Assessment Report Alkanes, C14-17, chloro (MCCP), Part II – Human Health Draft of February 2008.

EU Risk Assessment Report Benzyl butyl phthalate (BBP), Final Draft (2005).

EU Risk Assessment Report bis(2-ethylhexyl)phthalate (DEHP), Final Report (2008).

EU Risk Assessment Report Diantimony trioxide, Draft Report (2008).

European Commission (2000): Environmental Issues of PVC, Green Paper, Brussels.

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, Final report, Ottawa.

Fraunhofer Institut für Umweltchemie und Ökotoxikologie (1999): Annual Report 1999, S. 49-52.

Greenpeace International (2005): Recycling of Electronic Wastes in China & India: Workplaces & Environmental Contamination, report.

Hamm, S.; Schulte, J.; Strikkeling M.; and Maulshagen, A. (1999): Determination of polybrominated Diphenylethers (PBDEs) and eight polybrominated Dibenzodioxin (PBDD) and Dibenzofuran (PBDF) isomers in a HIPS/SB2O3/DecaBDE plastic before and after recycling, 19th International Symposium Dioxins99.

HDPUG (2008): Halogen Free Properties Project for Electronics Products. http://www.hdpug.org/sites/38788/pdf/hdp_hf_project_press_release.pdf.

Hicks, C, Dietmar, R. & Eugster, M. (2005): The recycling and disposal of electrical and electronic waste in China – legislative and market response. In: Environmental Impact Assessment Review 25: 459-471.

HP Standard 011 General Specification for the Environment (2007).

Huismann, J., Magalini, F., Kuehr, R., Maurer, C., Ogilvie, S., Poll; J., Delgado, C., Artim, E., Szezak, J. & Stevels, A. (2007): 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE). UNU, Bonn.

Illinois EPA (2007): Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues; A report to the Governor and the General Assembly; http://www.epa.state.il.us/reports/decabde-study/index.html.

iNEMI (International Electronic Manufacturing Initiative) (2007): Halogen-Free Project. http://www.inemi.org/cms/projects/ese/halogen_free_PhasesII-III.html.

International Antimony Association (2008): Summary of currently available scientific data on diantimony trioxide, Background: Risk assessment of diantimony trioxide.

Janet, K., Chan, Y.; Xing, G.H.; Xu, Y.; Liang, Y.; Chen, L.X.; Wu, S.C.; Wong, Chirs, K.C.; Leung, Cliement, K.M.; and Wong, M.H. (2007): Body Loadings and Health Risk Assessment of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans at an Intensive Electronic Waste Recycling Site in China, Environmental Science & Technology / Vol. 41, NO, 22, 2007.

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

Johnson-Restrepo, B. et al. (2008): Tetrabromobisphenol A (TBBPA) and hexabromocyclododecanes (HBCDs) in tissues of humans, dolphins, and sharks from the United States; Chemosphere 70 (2008) 1935–1944.

KEMI (2005): Survey and technical assessment of alternatives to decabromodiphenyl ether (decaBDE) in plastics. Report No. 1/05. http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport1_05.pdf.

KEMI (2006): Survey and technical assessment of alternatives to TBBPA and HBCDD. Report No. 1/06. https://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_06.pdf.

KEMI (2007): Strategy for limiting risks, Revision 1 – Hexabromocyclododecane (HBCDD), 18 December 2007, Swedish Chemicals Agency, Sweden; ES-25a-2007 Rev.1.

Kent, M.S., Corbett, M.L. & Glavin, M. (2007): Characterization and Analysis of Airborne Metal Exposures among Workers Recycling Cellular Phones, Brush Wellman Inc., Elmore, OH.

Knudson, T. (2008): A qualitative overview of the use of beryllium, beryllium-containing alloys and beryllium oxide ceramic in electrical and electronic equipment (EEE), Brush Wellman Inc., Elmore, OH.

Kuch, B.; Weber, R. (2003): Relevance of BFRs and thermal conditions on the formation pathways of brominated and brominated–chlorinated dibenzodioxins and dibenzofurans, Environment International 29, 699-710.

Lassen, C. (2006): Use of deca-BDE and its alternatives in electrical and electronic equipment. Preliminary list of alternatives. COWI. 25-1-2006.

Lemieux, P.M.; Stewart, E.S.; Ryan, J.V. (2002): Polit-scale studies on the effect of bromine addition on the emissions of chlorinated organic combustion by-products, Waste Mangement 22, 381-389

Leung, A.O.; Luksemburg, W.J.; Wong, A.S.; and Wong, M.H. (2007): Spatial Distribution of Polybrominated Diphenyl Ethers and Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China. Environ. Sci. Technol. 2007, 41, 2730-2737.

Li, H.; Feng, J.; Sheng, G.; Lü, S.; Fu, J.; Peng, P.; and Man, R. (2008): The PCDD/F and PBDD/F pollution in the ambient atmosphere of Shanghai, China, Chemosphere 70, 576-583.

Li, H.; Yu, L.; Sheng, G.; Fu, J.; and Peng, P. (2007): Serve PCDD/F and PBDD/F Pollution in Air around an Electronic Waste Dismantling Area in China, Environ. Sci. Technol. 2007, 41, 5641-5646.

Lowell Center for Sustainable Production (2005): Decabromodiphenylether – an investigation of non-halogen substitutes in electronic enclosures and textile applications. University of Massachusetts, Lowell http://www.sustainableproduction.org/downloads/DecaBDESubstitutesFinal4-15-05.pdf.

Manhart, A. (2007): Key social impacts of electronics production and WEEE-recycling in China. Öko-Institut, Freiburg.

Marzi, T. & Beard, A. (2006): The ecological footprint of flame retardants over their life cycle- A case study on the environmental profile of new phosphorus based flame retardants. Flame Retardants 2006 Conference. Interscience. ISBN 0954121678. pp. 21-30.

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.

Morose, G. (2006): An overview of alternatives to Tetrabromobisphenol A (TBBPA) and Hexabromocyclododecane (HBCD). Lowell Center for Sustainable Production, University of Massachusetts, Lowell http://sustainableproduction.org/downloads/AternativestoTBBPAandHBCD.pdf.

National Institute of Environmental Health Sciences (2005): 11th ed. Report on Carcinogens, Beryllium and beryllium compounds, Retrieved April 10th, 2008 from http://ntp.niehs.nih.gov/ntp/roc/eleventh/profiles/s022bery.pdf.

Ogilvie, S.M. (2004): WEEE & Hazardous substances; A report produced for DEFRA, AEA Technology.

Öko-Institut e.V. (2007): Entwicklung von thermoplastischen Leiterplatten als Beitrag zur Kreislaufwirtschaft; Endbericht der Qualifizierungsphase.

Olsman, H.; Engwall, M.; Kammann, U.; Klempt, M.; Otte, J.; von Bavel, B.; and Hollert, H. (2007): Reletive Differences in Aryl Hydrocarbon receptor-mediated response for 18 polybrominated and mixed halogenated Dibenzo-p-dioxins and – furans in cell lines form four different species, Environmental Toxicology and Chemistry, Vol. 26, No. 11, pp. 2448-2454, 2007.

Osibanjo, O. & Nnorom, I.C. (2007): The challenge of electronic waste (e-waste) management in developing countries. Waste Management Research 25 (6): 489-501.

OSPAR Commission (2003, updated 2006): Octylphenol; Hazardous Substances Series.

OSPAR Commission (2005, updated 2006): OSPAR Background Document on Phthalates.

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.

Paustenbach, D.J., Madl, A.K. &Greene, J.F. (2001): Identifying an Appropriate Occupational Exposure Limit (OEL) for Beryllium: Data Gaps and Current Research Initiatives, Applied Occupational and Environmental Hygiene, Vol. 16, Nr. 5, May 2001, pp. 527-538(12).

PE EUROPE GmbH, Institut für Kunststoffkunde und Kunststoffprüfung (IKP), Instituttet for Produktudvikling (IPU), DTU, RANDA GROUP (2004): Life Cycle Assessment of PVC and of principal competing materials, Final Report, Commissioned by the European Commission Brussels, Retrieved April 9th, 2008 from http://europa.eu.int/comm/enterprise/chemicals/sustdev/pvc-final_report_lca.pdf.

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.

Postle, M., Cordon, C., van den Berg, M., and Sanderson, T., (2000): The Availability of Substitutes for Soft PVC Containing Phthalates in Certain Toys and Children Articles, Risk & Policy Analysts Limited, Research Institute for Toxicology, final report prepared for European Commission.

Puckett, J., Westervelt, S., Gutierrez, R. & Takamiya, Y. (2005): The digital dump: Exporting re-use and abuse to Africa. Basel Action Network (BAN), Seattle.

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.

Schlummer, M; Gruber, L; Mäurer, A; Wolz, G; van Eldik, R (2007): Characterisation of polymer fractions from waste electrical and electronic equipment (WEEE) and implications for waste management, Chemosphere 67 1866-1876.

Schuhmacher-Wolz, U. & Schneider, K. (2004): Addendum Beryllium und Verbindungen, in Eikmann, T. (2007), Gefährdungsabschätzung von Umweltschadstoffen, Erich Schmidt Verlag.

SFT (2007a): Draft of new chapter concerning consumer products in the Norwegian Product Regulations: Chap X: Hazardous substances in consumer products; Norwegian Pollution control Authority.

SFT (2007b): Impact assessment of a proposal for prohibition on certain hazardous substances in consumer products; Norwegian Pollution control Authority.

Siemens (2006): Environmentally Compatible Products, Part 2: Hazardous substances, list of prohibited substances, list of substances to be avoided; Siemens Norm SN36350-2.

Söderström, G and Marklund, S, (2002): PBCDD and PBCDF from Incineration of Waste-Containing Brominated Flame Retardants, Environ. Sci. Technol. 2002, 36, 1959-1964.

Söderström, G and Marklund, S, (2004): Formation of PBCDD and PBCDF during Flue Gas Cooling, Environ. Sci. Technol. 2004, 38, 825-830.

Sony (2007): Management regulations for the environment-related substances to be controlled which are included in parts and materials.

Sony Ericsson (2007): The Sony Ericsson Lists of Banned and Restricted Substances.

Sweden (2008a): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Proposal for identification of Hexabromocyclododecane as a SVHC.

Sweden (2008b): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Proposal for identification of DEHA as a SVHC.

Takahashi, S; Kunisue, T; Isobe, T; Noda, S; Subramanian, A; Kajiwara, N; Tana, TS; Viet, PH; Miyazaki, T; Sakai, S; Tanabe,S, (2006): Polybrominated diphenyl ethers and dioxin-related compounds detected in soil samples form waste dumping sites in Asian developing countries, Organohalogen Compounds Vol. 68 (2006).

TNO – Netherlands Organisation for Applied Scientific Research (2001): Alternatives for phthalates. TNO-Report STB-01-55, Delft.

UBA (1999), Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC, Erich Schmidt Verlag, Berlin.

UBA (1999), Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC, Erich Schmidt Verlag, Berlin.

UBA – Umweltbundesamt (1999): Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC. Erich Schmidt Verlag, Berlin.

UBA – Umweltbundesamt (2000): Erarbeitung von Bewertungsgrundlagen zur Substitution umweltrelevanter Flammschutzmittel. Band III: Toxikologisch-ökotoxikologische Stoffprofile ausgewählter Flammschutzmittel.

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.

UBA – Umweltbundesamt (2001b): Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals; Results and summary overview; Report No. UBA-FB 000171/1.

UBA – Umweltbundesamt (2001c): Erarbeitung von Bewertungsgrundlagen zur Substitution umweltrelevanter Flammschutzmittel. Band II: Flammhemmende Ausrüstung ausgewählter Produkte – anwendungsbezogene Betrachtung: Stand der Technik, Trend, Alternativen. UBA-Texte 26/01. http://www.umweltbundesamt.de/uba-info-medien/mysql_medien.php?anfrage=Kennummer&Suchwort=1966.

UBA – Umweltbundesamt (2001d): Erarbeitung von Maßnahmenvorschlägen zur Substitution umweltrelevanter Flammschutzmittel bei Leiterplatten, Außengehäusen für IT- und TV-Geräte sowie Polyurethan-Dämm- und Montageschäumen. Workshop-Berichte.

UBA – Umweltbundesamt (2003), Guidance for the use of environmentally sound substances, Part 5.1: Plasticizers; Leitfaden zur Anwendung umweltverträglicher Stoffe. 5.1 Weichmacher, UBA, Berlin, Internet publikation at http://www.umweltdaten.de/umweltvertraegliche-stoffe/Teil5_1.pdf.

UBA – Umweltbundesamt (2007): Phthalate – Die nützlichen Weichmacher mit unerwünschten Eigenschaften http://www.umweltbundesamt.de/uba-info-presse/hintergrund/weichmacher.pdf.

UBA – Umweltbundesamt (2008): Bromierte Flammschutzmittel-Schutzengel mit schlechten Eigenschaften? http://www.umweltbundesamt.de/uba-info-presse/hintergrund/flammschutzmittel.pdf

UK REACH Competent Authority (2008): Annex XV dossier: Proposal for identification of a substance as a CMR Cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern; Substance name: Alkanes, C10-13, chloro.

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.

Van den Berg, M.; Birnbaum, L.S.; Denison, M.; De Vito, M.; Farland, W.; Feeley, M.; Fiedler, H.; Hakansson, H.; Hanberg, A.; Hauws, L.; Rose, M.; Safe, S.; Schrenk, D.; Tohyama, C.; Tritscher, A.; Tuomisto, J.; Tyskling, M.; Walker, N.; and Peterson, R.E. (2006): The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds, Advance Access publication July 7, 2006.

Vehlow, J.; Bergfeldt, B.; Jay, K.; Seifert, H.; Wanke, T.; Mark, F.E. (2000): Thermal Treatment of E+E Waste Plastics, Waste Management & Research 18, 131-140.

Wang, L.C.; Tsai, C.H.; Chang-Chien, G. and Hung, C.H. (2008): Characterization of Polybrominated Dibenzo-p-dioxins and Dibenzofurans in Different Atmospheric Environments, Environ. Sci. Technol. 2008, 42, 75-80.

Wolf, M; Ernst, T; Müller, B; Popp, R; Van Eldik, R: Bewertung und Optimierung von Verfahren zum Recycling flammgeschüzter Kunststoffe aus der Elektrotechnik, BayFORREST-Forschungsvorhaben F116.

Wong, M.H.; Wu, S.C.; Deng, W.J.; Yu, X.Z.; Luo, Q.; Leung, A.O.; Wong, C.S.; Luksemburg, W.J.; Wong, A.S. (2007): Export of toxic chemicals – A review of the case of uncontrolled electronic- waste recycling, Environmental Pollution 149, 131-140.

9 Annexes

9.1 Definition of dangerous substances in accordance with Council Directive 92/32/EEC of 30 April 1992 amending for the seventh time Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances

Article 2: The following are "**dangerous**" within the meaning of this Directive:

(a) explosive substances and preparations: solid, liquid, pasty or gelatinous substances and preparations which may also react exothermically without atmospheric oxygen thereby quickly evolving gases, and which, under defined test conditions, detonate, quickly deflagrate or upon heating explode when partially confined;

(b) oxidizing substances and preparations: substances and preparations which give rise to a highly exothermic reaction in contact with other substances, particularly flammable substances;

(c) extremely flammable substances and preparations: liquid substances and preparations having an extremely low flash-point and a low boiling-point and gaseous substances and preparations which are flammable in contact with air at ambient temperature and pressure;

(d) highly flammable substances and preparations:

– substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or

– solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or

– liquid substances and preparations having a very low flash-point, or

– substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities;

(e) flammable substances and preparations: liquid substances and preparations having a low flash-point;

(f) very toxic substances and preparations: substances and preparations which in very low quantities cause death or acute or chronic damage to health when inhaled, swallowed or absorbed via the skin;

(g) toxic substances and preparations: substances and preparations which in low quantities cause death or acute or chronic damage to health when inhaled, swallowed or absorbed via the skin;

(h) harmful substances and preparations: substances and preparations which may cause death or acute or chronic damage to health when inhaled, swallowed or absorbed via the skin;

(i) corrosive substances and preparations: substances and preparations which may, on contact with living tissues, destroy them;

(j) irritant substances and preparations: non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, may cause inflammation;

(k) sensitizing substances and preparations: substances and preparations which, if they are inhaled or if they penetrate the skin, are capable of eliciting a reaction of hypersensitization such that on further exposure to the substance or preparation, characteristic adverse effects are produced;

(l) carcinogenic substances and preparations: substances or preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence;

(m) mutagenic substances and preparations: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce heritable genetic defects or increase their incidence;

(n) substances and preparations which are toxic for reproduction: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may produce, or increase the incidence of, non-heritable adverse effects in the progeny and/or an impairment of male or female reproductive functions or capacity;

(o) substances and preparations which are dangerous for the environment: substances and preparations which, were they to enter the environment, would present or may present an immediate or delayed danger for one or more components of the environment.

9.2 Criteria for the identification of persistent, bioaccumulative and toxic substances, and very persistent and very bioaccumulative substances (according to REACH)

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.

9.3 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	

9.4 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[87] 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						

---

[87] 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).

9.5 Inventory of hazardous substances (meeting the criteria for classification as dangerous in accordance with Directive 67/548/EEC) in EEE

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC
1	Tetrabromo bisphenol A	79-94-7	Reactive FR in PCB laminates; Additive FR in ABS	Proposed classification: N; R50/53
2	Hexabromocyclododecane (HBCDD)	25637-99-4	Flame retardant in High Impact Polystyrene (HIPS)	Proposed classification: N R50-53;
3	Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	Plasticizer in PVC cables; Dielectric fluid in capacitors; Encapsulation/potting of electronics components	Repr. Cat. 2; R60-61
4	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
5	Dibutylphthalate (DBP)	84-74-2	Plasticizer in PVC cables; Encapsulation/potting of electronics components	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50
6	Medium-chained chlorinated paraffins (MCCP) (Alkanes, C14-17, chloro)	85535-85-9	Secondary plasticizer in PVC (cable); Flame retardant	Proposed classification: N; R50/53 ED Cat. 1
7	Short-chained chlorinated paraffins (SCCP) (Alkanes, C10-13, chloro)	85535-84-8	Flame retardant in power supplies; Plasticizer in connector wires	Carc. Cat. 3; R40 N; R50-53
8	Nonylphenol/ Nonylphenol ethoxylates	84852-15-3 and 25154-52-3 /	In curing systems in for epoxy resins; high temperature resistant module potting, current transformer potting, electrically conductive adhesives	Xn; R22; C; R34 N;R50-53

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC
		9016-45-9		
9	Diarsenic trioxide; arsenic trioxide[88]	1327-53-3	Fining agent in certain special glasses and glass ceramics	Carc. Cat. 1; R45 T+; R28 C; 34 N; R50-53
10	dinickel trioxide[89]	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)	Carc. Cat. 1; R49 R43 R53
11	Beryllium metal	7440-41-7	Beryllium metal and composites: - Optical instruments, - X-ray windows; Beryllium-containing alloys: - Current carrying springs, - Integrated circuitry sockets	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43
12	Beryllium oxide (BeO)	1304-56-9	BeO ceramic applications: Laser bores and tubes	Carc. Cat. 2; R49 T+; R26 T; R25-48/23 Xi; R36/37/38 R43
13	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; Used as catalyst in PET film manufacture	Carc Cat. 3, Xn, R40

---

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

[89] 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	Classification in accordance with 67/548/EEC
14	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	Xn; R20/22 N; R51-53
15	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	Repr. Cat. 3; R62 Xi; R37-41 R43 Endocrine disruptor, Cat 1 (according to EDS database)
16	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 demonstrated that the substance from which it was produced is not a carcinogen.[90]
17	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	Carc. Cat. 3; R40 T; R23/24/25 C; R34

---

[90] 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-carcinogenic, 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	Classification in accordance with 67/548/EEC
			temperature is possible; Insulation finish on copperwire	R43
18	Nickel[91]	7440-02-0	Used in pigments; 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	Carc. Cat. 3; R40 R43
19	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, May be used as a catalyst; Contained in specific ceramic materials	Muta. Cat. 3; R68 Repr. Cat. 3; R63 T; R48/23 Xn; R20/22 Xi; R37 N; R51-53
20	Arsenic / arsenic compounds[92]	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	T; R23/25 N; R50-53

---

[91] 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	Classification in accordance with 67/548/EEC
21	Gallium arsenide	1303-00-0	Semiconductor substrate, dopant in semiconductor material, substrate in LED applications	-
22	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 special glasses	T; R23/25 R33 R53
23	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
24	cobalt	7440-48-4	Used in special alloys and in electroplated coatings such as NiFeCo; 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	R42/43 R53

---

[92] 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	Classification in accordance with 67/548/EEC
			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	
25	phenyl bis(2,4,6-trimethyl-benzoyl)-phosphine oxide	162881-26-7	Used in X-ray detectors (Categories 8 & 9).	R43 R53
26	thallium	7440-28-0	Used in HID lamps; Used in certain ceramic materials in medical devices; Contained in AU plating solutions; Dopant used in the manufacture of digital medical x-ray detectors	T+; R26/28 R33 R53
27	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	R43
28	Synthetic vitreous fibres[93] -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;
29	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	Xi; R37/38 R43

---

[93] 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

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC
			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)	
30	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
31	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
32	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
33	Chlorinated hydrocarbons	various	Solvents, cleaning and degreasing agents	Carc.Cat.3; R40
34	aluminium powder (stabilised)	-	Aluminium metal is used in castings and sheet metal, not in powder form	F; R15 R10
35	chlorine	7782-50-5	Chlorine compounds used in several applications, mainly related to polymeric materials	T; R23 Xi; R36/37/38 N; R50
36	red phosphorus	7723-14-0	Flame retardant in certain types of plastics	F; R11 R16 R52-53
37	magnesium, powder or turnings	-	Magnesium metal is used in castings, not in powder form	F; R11-15
38	magnesium powder (pyrophoric)	7439-95-4	Magnesium metal is used in castings, not in powder form	F; R15-17
39	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
40	zinc powder - zinc dust (stabilized)	7440-66-6	Main use of Zinc in metal alloys, not used in powder form	N; R50-53

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC
41	fluorine	7782-41-4	Mainly in fluoropolymers and other fluorine compounds	R7 T+; R26 C; R35
42	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
43	white phosphorus	12185-10-3	May be present in certain plastics, metallic- or ceramic materials	F; R17 T+; R26/28 C; R35 N; R50
44	barium peroxide	1304-29-6	May be present in certain plastics, metallic- or ceramic materials	O; R8 Xn; R20/22
45	potassium hydroxide; caustic potash	1310-58-3	May be present in certain plastics, metallic- or ceramic materials	Xn; R22 C; R35
46	sodium hydroxide; caustic soda	1310-73-2	May be present in certain plastics, metallic- or ceramic materials	C; R35
47	manganese dioxide	1313-13-9	May be present in certain plastics, metallic- or ceramic materials	Xn; R20/22
48	molybdenum trioxide	1313-27-5	May be present in certain plastics, metallic- or ceramic materials	Xn; R48/20/22 Xi; R36/37
49	sodium peroxide	1313-60-6	May be present in certain plastics, metallic- or ceramic materials	O; R8 C; R35
50	zinc oxide	1314-13-2	May be present in certain plastics, metallic- or ceramic materials	N; R50-53
51	phosphorus pentoxide	1314-56-3	May be present in certain plastics, metallic- or ceramic materials	C; R35
52	dicopper oxide; copper (I) oxide	1317-39-1	May be present in certain plastics, metallic- or ceramic materials	Xn; R22 N; 50-53
53	magnesium hexafluorosilicate	16949-65-8	May be present in certain plastics, metallic- or ceramic materials	T; R25
54	aluminium phosphide	20859-73-8	May be present in certain plastics, metallic- or ceramic materials	F; R15/29 T+; R28 R32 N; R50
55	sodium carbonate	497-19-8	May be present in certain plastics, metallic- or ceramic materials	Xi; R36

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC
56	barium carbonate	513-77-9	May be present in certain plastics, metallic- or ceramic materials	Xn; R22
57	zirconium powder (pyrophoric)	7440-67-7	May be present in certain plastics, metallic- or ceramic materials	F; R15-17
58	calcium	7440-70-2	May be present in certain plastics, metallic- or ceramic materials	F; R15
59	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
60	calcium carbide	75-20-7	May be present in certain plastics, metallic- or ceramic materials	F; R15
61	copper sulphate	7758-98-7	May be present in certain plastics, metallic- or ceramic materials	Xn; R22 Xi; R36/38 N; R50-53
62	bromine	7726-95-6	Mostly in flame retardant compounds	T+; R26 C; R35 N; R50
63	lithium	7439-93-2	Mostly in Li-ion batteries	F; R14/15 C; R34
64	Dimethylformamide (DMF)[94]	68-12-2	High voltage/capacity aluminium foil electrolytic capacitors; power supplies; Printed wiring board epoxy: epoxy hardener material	Repr. Cat. 2; R61 Xn; R20/21 Xi; R36

---

[94] According to industry information DMF is not used anymore in EEE.

9.6 Applicable Laws and Regulations of banned and restricted substances

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
1	Arsenic/arsenic compounds	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	T; R23/25 N; R50-53	Restriction by Directive 76/769/EEC and amendments[95] (item 20) / Regulation (EC) 1907/2006 (REACH), Annex XVII [96] (item 19): 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

---

[95] COUNCIL DIRECTIVE of 27 July 1976 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 (76/769/EEC) (OJ L 262, 27.9.1976, p. 201)

[96] 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

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
					the preservative is completed. (ii): Relating to wood treated with CCA solutions in industrial installations according to point (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: – 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

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
					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)	117-81-7	Plasticizer in PVC cables	Repr. Cat. 2; R60-61	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; Regulation (EC) 1907/2006 (REACH), Annex XVII (item 51)
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	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; Regulation (EC) 1907/2006 (REACH), Annex XVII (item 51)
4	Dibutylphthalate (DBP)	84-74-2	Plasticizer in PVC cables; Encapsulation/potting of electronics components Silver conductive paint for variable resistors	Repr. Cat. 2; R61 Repr. Cat. 3; R62 N; R50	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; Regulation (EC) 1907/2006 (REACH), Annex XVII (item 51)
5	DI-N-Octylphthalate (DNOP)	117-84-0	Plasticizer in PVC cables		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; Regulation (EC) 1907/2006 (REACH), Annex XVII (item 52)
6	Diisononyl phthalate (DINP)	28553-12-0 and	Plasticizer in PVC cables		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

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
		68515-48-0			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; Regulation (EC) 1907/2006 (REACH), Annex XVII (item 52)
7	Nickel	7440-02-0			Restriction by Directive 76/769/EEC and amendments (item 28) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 27): 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, – 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.

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
8	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	Restriction by Directive 76/769/EEC and amendments (item 28) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 27)
9	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	Restriction by Directive 76/769/EEC and amendments (item 28) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 27)
10	Nonylphenol / Nonylphenol ethoxylates	84852-15-3 and 25154-52-3 / 9016-45-9			Restriction by Directive 76/769/EEC and amendments (item 46) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 46) for the following uses: - cleaning - textiles, leather processing - emulsifier in agriculture - metal working - pulp/paper - cosmetic + personal care - co-formulant in pesticides and biocides
11	Perfluorooctane sulfonates	1763-23-1	Photoresists or antireflective coatings		Restriction by Directive 76/769/EEC and amendments (item 52)
12	PCBs Polychlorinated Biphenyls	1336-36-3 and various others	Not used anymore in electrical equipment		Restricted by Directive 76/769/EEC and amendments (item 1); Stockholm Convention on Persistent Organic Pollutants; Regulation (EC) No 850/2004 [97]

---

[97] REGULATION (EC) No 850/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
13	PCT Polychlorinated Terphenyls	61788-33-8 and various others	Electrical insulation medium, Plasticizers, fire retardants, coatings for electrical wire and cable, dielectric sealants		Restriction by Directive 76/769/EEC and amendments (item 1) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 1)
14	PCN Polychlorinated Naphtalenes	70776-03-3			OSPAR List of Chemicals for priority Action (Update 2007)
15	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.		Restriction by Directive 76/769/EEC and amendments (item 42) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 27): 1. 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 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.
16	Tributyl Tin (TBT) compounds Triphenyl Tin (TPT) compounds	various	Stabilizer, antioxidant, antibacterial and antifungal agents, antifoulant, antiseptic, anti-fungal agent, paint, pigment, antistaining		Restriction by Directive 76/769/EEC and amendments / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 20): 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 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

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
					use in the treatment of industrial waters. Tributyltin compounds are listed as a Water Framework Directive Priority Hazardous Substance
17	Tributyl Tin Oxide (TBTO)	56-35-9	antiseptic, antifungal agent, paint, pigment, antistaining, refrigerant, foaming agent, extinguishant		Restriction by Directive 76/769/EEC and amendments / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 20); Confirmed as a PBT substance by the EU PBT Working Group; Tributyltin compounds are listed as a Water Framework Directive Priority Hazardous Substance
18	Dinickel trioxide	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)		Restriction by Directive 76/769/EEC and amendments (item 28) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 27)
19	Diarsenic trioxide	1327-53-3	Fining agent in certain special glasses and glass ceramics		Restriction by Directive 76/769/EEC and amendments (item 20) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 19)
20	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	Restriction by Directive 76/769/EEC and amendments (item 6) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 6)
21	Specific Azocolourants and azodyes (which form certain aromatic amines)	Various	Pigment, dyes, colorants		Restriction by Directive 76/769/EEC and amendments (item 43) / Regulation (EC) 1907/2006 (REACH), Annex XVII (item 43)

ID	Substance name	CAS-Nr.	Main use in EEE	Classification in accordance with 67/548/EEC	Key legal and regulatory information
22	Ozone Depleting Substances and Hydrochlorofluorocarbons	Various	Refrigerant, foaming agent, insulation extinguishant		REGULATION (EC) No 2037/2000 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 June 2000 on substances that deplete the ozone layer

9.7 Allocation of hazardous substances to electrical and electronic components

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
Connectors	Connector Metal Housing	0,05	-	-	1,41	100	ZVEI Umbrella Spec.	
	Connector Plastic Housing	0,44	-	-	1,00	100	ZVEI Umbrella Spec.	
Connectors / Cable Assemblies	Printer cable, without plugs	-	-	29,17	72,92	300	EcoInvent	1m length
	....	…	…	…	…			
Fuses and arresters	Surge voltage arrester	-	-	-	-	2	ZVEI Umbrella Spec.	
Semiconductor	Plastic axial diode	3,18	-	-	-	1	STMicroelectronics	Encapsulation
	Surface mount diode in melf packages	0,24	-	-	-	0	STMicroelectronics	Encapsulation
	Power schottky and rectifier diode	2,47	-	-	-	27	STMicroelectronics	Encapsulation
	Trisil, transil and schottky diodes in plastic packages	3,56				0	STMicroelectronics	Encapsulation
	Thyristors	2,89				20	STMicroelectronics	Encapsulation
	Small signal transistors in metal can packages	-	-	-	-	1	STMicroelectronics	Encapsulation
	Power products in TO3 packages	-	-	-	-	15	STMicroelectronics	Encapsulation
	Small signal transistors in TO92 package	5,90	-	-	-	0	STMicroelectronics	Encapsulation
	Small outline transistors and diodes –	7,44	-	-	-	10	STMicroelectronics	Encaps., Glue

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
	low power							
	Small outline transistors and diodes – high power	2,20	-	-	-	5	STMicroelectronics	Encapsulation
	Surface mount devices medium power transistors	4,34	-	-	-	1	STMicroelectronics	Encapsulation
	Through hole package medium power transistors	4,25	-	-	-	1	STMicroelectronics	Encapsulation
	Medium/high power transistor/thyristor isolated packages	5,22	-	-	-	5	STMicroelectronics	Encapsulation
	GBU package	5,75	-	-	-	4	STMicroelectronics	Encapsulation
	R.F. hermetic packages with stud	-	-	-	-	2	STMicroelectronics	
	R.F. ceramic packages with stud	-	-	-	-	5	STMicroelectronics	
	R.F. hermetic flanged packages	-	-	-	-	6	STMicroelectronics	
	R.F. studless ceramic packages	-	-	-	-	1	STMicroelectronics	
	R.F. ceramic flanged packages	-	-	-	-	10	STMicroelectronics	
	Ceramic dual in line package	-	-	-	-	5	STMicroelectronics	
	Frit-seal ceramic package with bulls-eye (lens)	-	-	-	-	9	STMicroelectronics	
	Side brazed ceramic dual in line package with and without lens	-	-	-	-	5	STMicroelectronics	
	J leaded chip carrier	-	-	-	-	3	STMicroelectronics	
	Ceramic leaded chip carrier	-	-	-	-	3	STMicroelectronics	
	Ceramic quad flat packages	-	-	-	-	5	STMicroelectronics	

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
	Ceramic pin grid array	-	-	-	-	10	STMicroelectronics	
	Dual in line plastic packages – frame 0.25	7,59	-	-	-	3	STMicroelectronics	
	Power dual in line plastic packages – frame 0.40	5,53	-	-	-	1	STMicroelectronics	
	Shrink dual in line plastic packages	7,90	-	-	-	5	STMicroelectronics	
	P-dip zeropower/timekeeper	5,78	-	-	-	10	STMicroelectronics	Encaps. and Filler
	Small outline plastic packages	7,51	-	-	-	1	STMicroelectronics	
	Shrink small outline plastic packages	7,51	-	-	-	0	STMicroelectronics	
	Power SO packages	4,17	-	-	-	1	STMicroelectronics	
	TO220 packages	2,31	-	-	-	2	STMicroelectronics	
	Multiwatt	2,19	-	-	-	6	STMicroelectronics	
	Pentawatt, heptawatt	2,31	-	-	-	2	STMicroelectronics	
	Flexiwatt packages	3,51	-	-	-	7	STMicroelectronics	
	Clipwatt packages	5,12	-	-	-	2	STMicroelectronics	
	Single in line plastic packages	4,19	-	-	-	1	STMicroelectronics	
	Plastic leaded chip carrier	7,29	-	-	-	3	STMicroelectronics	
	Thin quad flat packages	6,91	-	-	-	1	STMicroelectronics	
	Low quad flat packages	6,91	-	-	-	1	STMicroelectronics	
	Plastic quad flat packages	4,90	-	-	-	5	STMicroelectronics	
	High quad packages	4,04	-	-	-	3	STMicroelectronics	
	Thin small outline packages – frame	7,93	-	-	-	4	STMicroelectronics	

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
	Cu							
	Thin small outline packages – frame Alloy42	7,93	-	-	-	1	STMicroelectronics	
	Thin small small outline packages	7,08	-	-	-	1	STMicroelectronics	
	Low profile ball grid array packages	6,07	-	-	-	1	STMicroelectronics	Substr., Encaps., Glue
	Thin fine pitch ball grid array packages	6,07	-	-	-	0	STMicroelectronics	Substr., Encaps., Glue
	Low profile fine pitch ball grid array packages	6,07	-	-	-	1	STMicroelectronics	
	Plastic ball grid array packages	6,08	-	-	-	2	STMicroelectronics	
	Very-thin-profile fine pitch ball grid array packages	4,78	-	-	-	0	STMicroelectronics	
	Very thin fine pitch quad flat package no lead	4,09	-	-	-	0	STMicroelectronics	
	Flip chip CSP	-	-	-	-	0	STMicroelectronics	
	Micromodule (potting or molding process)	28,69	-	-	-	30	STMicroelectronics	Substr., Encaps., Glue
	Micromodule with metal ring	24,19	-	-	-	35	STMicroelectronics	Substr., Encaps., Glue
Electrolytic Capacitors	Speciality Polymer Aluminium Electrolytic Capacitor (SMD)	8,17	-	-	-	0	ZVEI Umbrella Spec.	Encapsulation
	Aluminium Electrolytic Capacitor (axial)	-	-	?	0,57	15	ZVEI Umbrella Spec.	Cover disk
	Aluminium Electrolytic Capacitor (radial)	-	-	?	1,65	8	ZVEI Umbrella Spec.	Cover disk
	Aluminium Electrolytic Capacitor (Screw)	-	-	?	2,00	1 000	ZVEI Umbrella Spec.	Cover disk

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
	Aluminium Electrolytic Capacitor (SMD)	-	-	-	-	1	ZVEI Umbrella Spec.	
	Aluminium Electrolytic Capacitor (Snap In)	-	-	-	0,50	30	ZVEI Umbrella Spec.	Cover disk
	Aluminium Electrolytic Capacitor (Snap In - TS type)	-	-	-	2,60	50	ZVEI Umbrella Spec.	
Ceramic Capacitors	Ceramic Capacitor MLCC	-	-	-	-	0	ZVEI Umbrella Spec.	
Metallized Film Capacitors	Metallized Film Capacitor (Boxed)	6,80	-	-	-	5	ZVEI Umbrella Spec.	Encapsulation
	Metallized Film Capacitor (uncoated)	-	-	-	-	3	ZVEI Umbrella Spec.	
	Metallized Film Capacitor (Film Chip Capacitor)	-	-	-	-	1	ZVEI Umbrella Spec.	
Tantalum Capacitors	Tantalum Capacitor (SMD)	6,43	-	-	-	0	ZVEI Umbrella Spec.	Encapsulation
Leaded Resistors	Cemented wirewound	-	-	-	-	5	ZVEI Umbrella Spec.	
	Cemented wirewound precision	-	-	-	-	3	ZVEI Umbrella Spec.	
	Professional power metal film	-	-	-	-	1	ZVEI Umbrella Spec.	
	Professional / precision	-	-	-	-	1	ZVEI Umbrella Spec.	
	Radial mounted power film	-	-	-	-	10	ZVEI Umbrella Spec.	
	Radial mounted power wirewound	-	-	-	-	10	ZVEI Umbrella Spec.	
	Fusible	0,34	-	-	-	0	ZVEI Umbrella Spec.	
	High Ohmic / High voltage	1,02	-	-	-	1	ZVEI Umbrella Spec.	
	Low Ohmic Surge	2,21	-	-	-	1	ZVEI Umbrella Spec.	

Group	Subgroup / Typical Components	TBBP-A [%]	HBCDD [%]	DEHP, BBP, DBP [%]	PVC (incl. Phthalates) [%]	Typical weight [g]	Source of data	Remark
	Low Ohmic	-	-	-	-	3	ZVEI Umbrella Spec.	
	Ultra precision	-	-	-	-	1	ZVEI Umbrella Spec.	
	Stand-up miniature power film	-	-	-	-	5	ZVEI Umbrella Spec.	
	Stand-up miniature power wirewound	-	-	-	-	5	ZVEI Umbrella Spec.	
	Standard metal film	-	-	-	-	0	ZVEI Umbrella Spec.	
SMD Resistors	SMD Array	17,00				0	ZVEI Umbrella Spec.	
	SMD Flat chip	0,27	-	-	-	0	ZVEI Umbrella Spec.	Insulation
	Power thickfilm flat chip	0,39	-	-	-	0	ZVEI Umbrella Spec.	
	Thick film flat chip	0,41	0,44	-	-	0	ZVEI Umbrella Spec.	
	MELF	-	-	-	-	0	ZVEI Umbrella Spec.	
Potentiometers	to be defined / differentiated	?	?	?	?		-	no data available
Thermistor NTC	Thermistor NTC (disk)	?	-	-	-	5	ZVEI Umbrella Spec.	Encapsulation
	Thermistor NTC (SMD)	-	-	-	-	0	ZVEI Umbrella Spec.	
Printed Circuit Boards	PCB 1/2 lay; 3,75 kg/m²	13,42	-	-	-	30	ZVEI Umbrella Spec.	100mm * 100mm
	PCB 6 lay; 4,5 kg/m²	11,65	-	-	-	33	ZVEI Umbrella Spec.	100mm * 100mm
	PCB 6 lay; 2 kg/m²	8,79	-	-	-	19	ZVEI Umbrella Spec.	100mm * 100mm

9.8 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
07.02.2008	Brussels	Hazardous Substances in EEE	Representatives of Orgalime
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
06.05.2008	Brussels	Expert Workshop in Brussels on proposed candidate substances	Experts from electronic industry, NGOs, national authorities