

ROHS Annex II Dossier for Diantimony trioxide (flame retardant). Restriction proposal for substances in electrical and electronic equipment under RoHS

Report No. 1

Substance Name: Diantimony trioxide (flame retardant)

EC Number: 215-175-0

CAS Number: 1309-64-4

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Table of Contents

List of Tables	6
Abbreviations	7
CONTEXT and SCOPE of the DOSSIER/ substance assessment	10
1. IDENTIFICATION, CLASSIFICATION AND LABELLING, LEGAL STATUS AND USE RESTRICTIONS	11
1.1. Identification	11
1.1.1. Name, other identifiers, and composition of the substance	11
1.1.2. Physico-chemical properties	12
1.2. Classification and labelling status	12
1.2.1. Classification in Annex VI Regulation No 1272/2008	12
1.2.2. Self-classification(s)	13
1.3. Legal status and use restrictions	13
1.3.1. Regulation of the substance under REACH	13
1.3.2. Other legislative measures	14
1.3.3. Non-governmental initiatives	15
2. USE IN ELECTRICAL AND ELECTRONIC EQUIPMENT	17
2.1. Function of the substance	17
2.2. Types of applications / types of materials	18
2.3. Quantities of the substance used	19
3. HUMAN HEALTH HAZARD PROFILE	21
3.1. Endpoints of concern	21
3.2. Existing Guidance values (DNELs, OELs)	22
4. ENVIRONMENTAL HEALTH HAZARD PROFILE	24
4.1. Endpoints of concern	25
4.2. Potential for secondary poisoning and bioaccumulation	25
4.3. Guidance values (PNECs)	26
5. WASTE MANAGEMENT OF ELECTRICAL AND ELECTRONIC EQUIPMENT	26
5.1. Description of waste streams	26
5.1.1. Main materials in the waste stream where the substance is contained	28
5.1.2. WEEE categories containing the substance	28
5.2. Applied waste treatment processes	29

5.2.1.	Initial treatment processes applied to the WEEE containing the substance of concern	29
5.2.2.	Treatment processes applied to wastes derived from WEEE containing the substance of concern	30
5.3.	Waste treatment processes relevant for assessment under RoHS	30
5.4.	Releases from (relevant) WEEE treatment processes	31
5.4.1.	Releases to air, water and soil from waste incineration plants	31
6.	EXPOSURE ESTIMATION DURING USE AND DURING WEEE TREATMENT	33
6.1.	Human exposure estimation	33
6.1.1.	Exposure of workers of EEE waste processing plants	33
6.1.2.	Exposure of neighbouring residents of EEE waste processing plants	36
6.1.3.	Consumer exposure	37
6.2.	Environmental exposure estimation	37
6.2.1.	Monitoring data: remote regions, biota	38
6.2.2.	Monitoring data: waste management	38
7.	IMPACT AND RISK EVALUATION	39
7.1.	Impacts on WEEE management as specified by Article 6 (1)a	39
7.2.	Risks for workers	40
7.3.	Risks for consumers and neighbouring residents	41
7.4.	Risks for the environment	41
8.	ALTERNATIVES	42
8.1.	Availability of substitutes / alternative technologies	42
8.1.1.	Alternatives to ATO as synergist for flame retardants	42
8.1.2.	Alternative flame retardants to the combination of halogenated flame retardants and ATO	43
8.1.3.	Alternative technologies	45
8.2.	Hazardous properties of substitutes	48
8.3.	Data basis for alternatives and uncertainties	52
8.4.	Conclusion on alternatives	52
9.	DESCRIPTION OF SOCIO-ECONOMIC IMPACTS	53
9.1.	Approach and assumptions	53
9.2.	Impact on chemicals industry	53
9.3.	Impact on EEE producers	54
9.4.	Impact on EEE users	54
9.5.	Impact on waste management	55
9.6.	Impact on administration	55

9.7.	Total socio-economic impact	55
10.	RATIONALE FOR INCLUSION OF THE SUBSTANCE IN ANNEX II OF ROHS	57
11.	REFERENCES	58
11.1.	Databases	58
11.2.	Contributions, documents and reports	58
12.	Appendix I: Contributions to 1st stakeholder consultation hold from 20 April 2018 to 15 June 2018	61

List of Tables

Table 1-1:	Substance identity and composition of diantimony trioxide	11
Table 1-2:	Overview of physico-chemical properties of diantimony trioxide	12
Table 1-3:	Classification according to part 3 of Annex VI, Table 3.1 (list of harmonized classification and labelling of hazardous substances) of Regulation (EC) No 1272/2008	13
Table 3-1:	International limit values for ATO provided by IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung in GESTIS International Limit Values	23
Table 3-2:	Guidance values for diantimony trioxide, bw = body weight	23
Table 4-1:	PNECs of diantimony trioxide	26
Table 5-1:	Initial treatment processes applied	29
Table 5-2:	Treatment processes for wastes derived from WEEE	30
Table 6-1:	Input parameters used in ECETOC TRA for worker exposure	34
Table 6-2:	Exposure estimates with ECETOC TRA for ATO in PROC 24a	35
Table 6-3:	Antimony concentration (GM (GSD) & range) in the collected inhalable fraction and OFC fraction from personal air sampling (exposure data for recycling workers) and from static sampling (exposure data for office workers) at three e-waste recycling plants in Sweden	36
Table 8-1:	Halogen-free (thus ATO-free) flame retardants according to the TCO Certified Accepted Substance List (further details on the substances in the following chapter)	45
Table 8-1:	Hazardous properties of substitutes for diantimony trioxide as a synergist	49
Table 8-2:	Hazardous properties of alternatives to halogenated flame retardants according to TCO generation 8	50

Abbreviations

ABS	Acrylonitrile Butadiene Styrene copolymers
AEM	Association of Equipment Manufacturers
A-PPE	Thermoset Polyphenylenether
ASD	AeroSpace and Defence Industries Association of Europe
ATH	Aluminium Trihydroxide
ATO	Diantimony Trioxide
BAF	Bioaccumulation Factor
BAUA	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (German Federal Institute for Occupational Safety and Health)
BCF	Bioconcentration Factor
BDP	Bisphenol A bis(diphenyl Phosphate)
BFR	Brominated Flame Retardant
BT	Bismaleimide Triazine
C&L	Classification and Labelling
CMR	Carcinogenic, Mutagenic or Reprotoxic
Co	Cobalt
CoRAP	Community Rolling Action Plan
DNEL	Derived No Effect Levels
ECHA	European Chemicals Agency
EDG	European Domestic Glass
EEE	Electrical and Electronic Equipment
ESGA	European Special Glass Association
ESIA	European Semiconductor Industry Association
EU RAR	European Risk Assessment Report
EVA	Polyethyl Co-Vinyl Acetate
FR	Flame Retardant
HBCDD	Hexabromocyclododecane
HFFR	Halogen Free Flame Retardant
Hg	Mercury

HIPS	High Impact Polystyrene
i2A	International Antimony Association
IEC	International Electrotechnical Commission
IED	Industrial Emissions Directive
IUPAC	International Union of Pure and Applied Chemistry
KEMI	Swedish Chemicals Agency
LCD	Liquid crystal display
LCP	Liquid crystal polymers
LIFT	Lateral Ignition and Flame spread Test
LOI	Limiting Oxygen Index
MC	Melamine Cyanurate
MDH	Magnesium (di)hydroxide
MPP	Melamine Polyphosphate
MSDS	Material safety data sheet
OEL	Occupational Exposure Limit
OEM	Original Equipment Manufacturer
PA	Polyamide
PBT	Persistent, Bioaccumulative, Toxic
PTMT	Polytetramethylterephthalate (=Poly Butylene Terephthalate)
PC	Polycarbonate
PWB	Printed Wiring Boards
PE	Polyethylene
PET	Poly Ethylene Terephthalate
PNEC	Predicted No Effect Concentration
PP	Polypropylene
PPE	Polyphenylenether
PPO	Polyphenylenoxide
PTFE	Poly(tetrafluoroethylene
PVC	Polyvinylchloride
RCR	Risk Characterisation Ratio

RDP	Resorcinol bis(diphenyl Phosphate)
SIN	SIN (Substitute it Now!) List of the NGO ChemSec
STOT RE	Specific target organ toxicity (repeated exposure)
SPIN	Substances in Preparations in Nordic Countries
TBBP-A	Tetrabrombisphenol A
TCP	Tricresyl Phosphate
TMC	Test and Measurement Coalition
TMF	Trophic Magnification Factor
TPP	Triphenyl Phosphates
UL	Underwriters Laboratories
US EPA	United States Environmental Protection Agency
vPvB	Very Persistent or Very Bioaccumulative
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie e. V.

CONTEXT and SCOPE of the DOSSIER/ substance assessment

The substance assessment of diantimony trioxide is being performed as part of the “*Study on the review of the list of restricted substances and to assess a new exemption request under RoHS 2 – Pack 15*”. With contract No. 07.0201/2017/772070/ENV.B.3 implementing Framework Contract No. ENV.A.2/FRA/2015/0008, a consortium led by Oeko-Institut for Applied Ecology has been assigned by DG Environment of the European Commission to provide technical and scientific support for the review of the list of restricted substances and to assess a new exemption request under RoHS 2. This study includes an assessment of seven substances and group of substances¹ with a view to the review and amendment of the RoHS Annex II list of restricted substances. The seven substances have been pre-determined by the Commission for this task. The detailed assessment is being carried out for each of the seven substances in line with a uniform methodology².

In the course of the substance assessment, a 1st stakeholder consultation was held from 20 April 2018 to 15 June 2018 to collect information and data for the seven substances under assessment. Information on this consultation can be found at Oeko-Institut’s project webpage at: <http://rohs.exemptions.oeko.info/index.php?id=289>.

For diantimony trioxide, a total of 14 contributions were submitted by different stakeholders. An overview of the contributions submitted during this consultation is provided in Appendix I. The contributions can be viewed at: <http://rohs.exemptions.oeko.info/index.php?id=290>.

Based on stakeholder input and publicly available information, the current dossier has been prepared, which is now subject to a 2nd stakeholder consultation. The aim of the 2nd consultation is to receive further information, data and comments:

- To provide clarity as to aspects on which data gaps still exist;
- to provide specific data for basing estimations where these are currently based on assumptions due to lack of data;
- to provide sector-specific data where current information does not allow making relevant distinction regarding the use in various EEE sectors;
- to comment on the general interpretations made regarding the current base of knowledge.

After the revision of the dossiers and their completion, a final stakeholder meeting shall be held to allow stakeholders to comment on the dossiers and particularly on conclusions and recommendations.

¹ For the sake of better readability hereafter substance will be used for single substances as well as group of substances.

² This methodology includes a dossier template for substance assessment which had been prepared by the Austrian Umweltbundesamt GmbH in the course of a previous study. The methodology for substance assessment has been revised based on various proposals from and discussions with stakeholders. Among others, revisions have been made to clarify when the Article 6(1) criteria are considered to be fulfilled and how the precautionary principle is to be applied. The methodology has also been updated in relation to coherence to REACH and other legislation and publicly available sources of relevance for the collection of information on substances have been updated and added. The methodology is available at <https://rohs.exemptions.oeko.info/index.php?id=341>

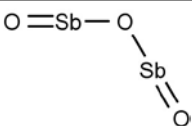
1. IDENTIFICATION, CLASSIFICATION AND LABELLING, LEGAL STATUS AND USE RESTRICTIONS

1.1. Identification

1.1.1. Name, other identifiers, and composition of the substance

The information compiled in the following table on the substance identity of diantimony trioxide originates from the ECHA information on substances database³ and the European Risk Assessment Report (EU RAR) on diantimony trioxide from 2008.⁴

Table 1-1: Substance identity and composition of diantimony trioxide

Chemical name	Diantimony trioxide
EC number	215-175-0
CAS number	1309-64-4
Index number in Annex VI of the CLP Regulation	051-005-00-X
Molecular formula	Sb ₂ O ₃
Molecular weight	291,49 g/mol
IUPAC name	oxostibanyl stibinate, dioxodistiboxane
Synonyms	Antimony (III) oxide Antimony (3+) oxide Antimony oxide (Sb ₂ O ₃) Antimony peroxide Antimony trioxide Antimony oxide Antimony sesquioxide Antimony white Flowers of antimony Senarmontite Valentinite Sesquioxide C.I. Pigment White 11 C.I. 77052 ATO, PATOX
Structural formula	
Degree of purity	ECHA database of registered substances lists different compositions and indicates different impurities The EU RAR indicates the purity for diantimony trioxide at 99.3 to 99.5 % (with the exception of wetted forms, for which a lower specification limit of 95 % was given)
Remarks	None

Source: European Chemicals Agency ECHA, Brief Profile: Entry for Diantimony trioxide (2018), <https://echa.europa.eu> and EU RAR (2008)

³ ECHA Brief Profile: Entry for Diantimony trioxide; <https://echa.europa.eu/de/brief-profile/-/briefprofile/100.013.796>, last viewed 19.04.2018

⁴ European Union Risk Assessment Report EU RAR (2008): Diantimony trioxide, November 2008; <http://www.echa.europa.eu/documents/10162/553c71a9-5b5c-488b-9666-adc3af5cdf5f>, last viewed 19.04.2018

1.1.2. Physico-chemical properties

The physico-chemical properties of diantimony trioxide are summarised in Table 1-2 below and were extracted from the ECHA's information on substances database⁵

Table 1-2: Overview of physico-chemical properties of diantimony trioxide

Property	Value
Physical state at 20°C and 101.3 kPa	Solid (100 %)
Melting/freezing point	656 °C
Boiling point	1,425 °C at 101.3 kPa
Vapour pressure	1.33 hPa at 574 °C
Water solubility	370 µg/L
Partition coefficient n-octanol/ water (log K _{ow})	No data available
Dissociation constant	No data available

Source: ECHA Brief Profile: Entry for Diantimony trioxide

1.2. Classification and labelling status

The Classification, Labelling and Packaging (CLP) regulation⁶ ensures that the hazards presented by chemicals are clearly communicated to workers and consumers in the European Union through classification and labelling of chemicals. Annex VI of Regulation No 1272/2008 lists substances where a harmonized classification exists based on e.g. human health concerns.

Annex VI of the CLP regulation is constantly adapted by engagement of Member State Competent Authorities and ECHA where new information becomes available, where existing data are re-evaluated or due to new scientific or technical developments or changes in the classification criteria.⁷

For an explanation on the human and environmental hazards, see section 3 and 4.

1.2.1. Classification in Annex VI Regulation No 1272/2008

For diantimony trioxide, there is a harmonised classification according to Regulation No 1272/2008, Table 3.1 of Annex VI for carcinogenicity Category 2, carrying the hazard statement code H351, i.e. suspected of causing cancer. For more details, see the following table.

⁵ Op. cit. ECHA Brief Profile: Entry for Diantimony trioxide

⁶ Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (REACH).

⁷ For further information, see <https://echa.europa.eu/regulations/clp/harmonised-classification-and-labelling>, last viewed 19.04.2018

Table 1-3: Classification according to part 3 of Annex VI, Table 3.1 (list of harmonized classification and labelling of hazardous substances) of Regulation (EC) No 1272/2008

Index No.	International Chemical ID	EC No.	CAS No.	Classification		Labelling			Spec. Conc. Limits, M-factors	Notes
				Hazard Class and Category Code(s)	Hazard statement code(s)	Pictogram, Signal Word Code(s)	Hazard statement code(s)	Suppl. Hazard statement code(s)		
051-005-00-X	antimony trioxide	215-175-0	1309-64-4	Carc. 2	H351	GHS08 Wng	H351	-	-	-

Source: Annex VI Regulation No 1272/2008; <https://echa.europa.eu/de/information-on-chemicals/annex-vi-to-clp>, last viewed 19.04.2018

The human health concerns for ATO are detailed in section 3.

1.2.2. Self-classification(s)

Manufacturers, importers or downstream users have to (self-)classify and label hazardous substances and mixtures to ensure a high level of protection of human health and the environment. If a harmonized classification is available, it should be applied by all manufacturers, importers or downstream users of such substances and of mixtures containing such substances.

However, mostly, suppliers decide independently as to the classification of a substance or mixture, which is then referred to as self-classification. Therefore, self-classification might indicate an e.g. additional hazard which is so far not reflected by the harmonized classification. The following assessment of the self-classification therefore emphasises cases where self-classifications differ and where additional hazards were notified in the self-classification.

The ECHA database C&L Inventory contains classification and labelling information on notified and registered substances received from manufacturers and importers. With regard to diantimony trioxide, there is a total number of 1,680 notifications (as of July 2018).⁸

To summarise, the various self-classifications, basically the same types of hazards are addressed as by the harmonised classification. Though in some cases the level of hazard may differ, or certain hazard types have been omitted, and given that the harmonised classification is assumed to have a higher standard of scrutiny, the differences in the self-classification compared to the harmonized classification are not further considered.

1.3. Legal status and use restrictions

1.3.1. Regulation of the substance under REACH

Diantimony trioxide was included in the Community Rolling Action Plan (CoRAP) by the German Federal Institute for Occupational Safety and Health (BAUA). The substance evaluation is currently ongoing. As initial grounds for concern, the following short list is published at the ECHA website:⁹

⁸ ECHA CL Inventory: Entry for Diantimony trioxide (2018); <https://echa.europa.eu/de/information-on-chemicals/cl-inventory-database/-/discli/details/16879>, last viewed 10.08.2018

- Carcinogenic,
- Exposure of workers,
- High (aggregated) tonnage,
- High RCR (which is the Risk Characterisation Ratio which is a comparison of exposure levels to predicted no-effect concentrations (PNECs) or derived no-effect levels (DNELs)),
- Other exposure / risk-based concern,
- Wide dispersive use.

According to the Justification Document for the Selection of a CoRAP Substance (BAuA 2016)¹⁰, diantimony trioxide is used as a reducing agent for Cr(VI) in cement, as a substitute for Fe(II)SO₄, a use that has not been addressed in the EU RAR (2008)¹¹. The BAuA argues that *“it should be examined whether antimony(III) oxide is a suitable substitute for Fe(II)SO₄. There are indications that the DNEL was not derived in accordance with the ECHA Guidance Chapter R.8 which gives rise to the concern of higher resulting RCRs [Risk Characterisation Ratios]¹² than those described by the registrants. Due to high tonnage and uses by professional workers, a high potential of exposure is anticipated.”*

1.3.2. Other legislative measures

Other legislative measures address antimony and its compounds as a group. As this also includes diantimony trioxide, these legal restrictions are compiled in the following:

- **Regarding human health issues,**
 - There was a proposal for community-wide measures to reduce risks, submitted by the Swedish Chemicals Agency KEMI in 2008.¹³ The proposal recommended establishing occupational exposure limit values for antimony trioxide according to Directive 98/24/EEC.¹⁴
 - Occupational exposure limits of 0.5 mg/m³ antimony trioxide on average and lower have been established in several EU countries (see section 3.2).
 - A migration limit of antimony trioxide is set
 - for plastics used in contact with foodstuffs by Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food Text with EEA relevance relating to plastic materials and articles intended to come into contact with foodstuffs.¹⁵

⁹ <https://echa.europa.eu/de/information-on-chemicals/evaluation/community-rolling-action-plan/corap-table/-/dislist/details/0b0236e180b91312>

¹⁰ BAUA German Federal Institute for Occupational Safety and Health (2016): Justification Document for the Selection of a CoRAP Substance; <https://echa.europa.eu/documents/10162/44adc62e-ff48-4ce8-9c4f-58dd8b77253a>

¹¹ Opt cit. EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

¹² Risk Characterisation Ratios (RCRs) are derived by comparing exposure levels to suitable predicted no-effect concentrations (PNECs) or derived no-effect levels (DNELs).

¹³ Swedish Chemicals Agency (2008): Proposal for Community-wide measures to reduce risks; Diantimony Trioxide; 2008-11-26; http://www.echa.europa.eu/documents/10162/13630/trd_sweden_diantimony_trioxide_en.pdf, last viewed 19.04.2018

¹⁴ Council Directive 98/24/EC on the protection of the health and safety of workers from the risks related to chemical agents at work

¹⁵ Specific migration limit SML = 0,02 mg/kg (expressed as Antimonium and analytical tolerance included)

- for toys or components of toys by Directive 2009/48/EC on the safety of toys.¹⁶
- A maximum level for antimony is set for water intended for human consumption by the Council Directive 98/83/EC on the quality of water for human consumption.¹⁷
- **Regarding environmental issues:**
 - The so-called IED Directive 2010/75/EU¹⁸ on industrial emissions (integrated pollution prevention and control) sets air emission limit values for waste incineration plants for antimony and its compounds. Accordingly, the average emission limit values for the following heavy metals over a sampling period of a minimum of 30 minutes and a maximum of 8 hours are set as concentrations in mass per cubic meter at 0,5 mg/m³ for antimony and its compounds, expressed as antimony (Sb).
 - According to Commission Decision 2014/955/EU amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC, any compound of antimony is characterized as a “heavy metal” and leads to a classification as hazardous waste.
 - Limit values for antimony (as Sb) are set by “Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II of Directive 1999/31/EC (2003/33/EC)”.¹⁹

Antimony is listed on the 2017 list of Critical Raw Materials of the EU (COM(2017) 490 final)²⁰. Materials appearing on this list have been identified as critical for the EU because possible risks of supply shortage (scarcity) and their impacts on the economy are higher than those of most of the other raw materials. Additional aspects (e.g. environmental, social) are not mentioned in the communication in this regard.

1.3.3. Non-governmental initiatives

The International Chemical secretariat (Chemsec) has specified and updates the SIN List, which identifies potential substances of concern. The purpose of this list is to put pressure on legislators to assess and where relevant address substances identified therein in the future in respect of relevant chemical legislation. Chemsec applies a number of categories for adding substances to the SIN List, including substances that can cause cancer, alter DNA or damage reproductive

¹⁶ Migration limits

- in dry, brittle, powder-like or pliable toy material: 45 mg/kg Antimony
- in liquid or sticky toy material: 11,3 mg/kg Antimony
- in scraped-off toy material: 560 mg/kg Antimony

¹⁷ 5,0 µg/l Antimony

¹⁸ Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast); <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN>, last viewed 24.07.2018

¹⁹ Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC(2003/33/EC); <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:011:0027:0049:EN:PDF>, last viewed 19.04.2018: See there “2.1.2.1. Leaching limit values” for waste acceptable at landfills for inert waste and limit values for non-hazardous waste”; antimony is abbreviated as Sb.

²⁰ EU COM (2017), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the 2017 list of Critical Raw Materials for the EU, Brussels, 13.9.2017, COM(2017) 490 final, available under: <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2017:0490:FIN>, last viewed 19.04.2018

systems (CMR properties); substances that do not easily break down and accumulate in the food chain (PBT/vPvB substances); and substances of equivalent concern that give rise to an equivalent level of concern in terms of potential damage to health and environment (such as substances with endocrine disrupting properties).

Diantimony trioxide is considered “carcinogen” according to the harmonized classification in the EU.²¹ Furthermore, diantimony trioxide is added to the SIN List not only for this reason but also because “*reprotoxic effects have been reported*”.²²

²¹ <https://echa.europa.eu/de/brief-profile/-/briefprofile/100.013.796> last visited 15.11.2019

²² SIN list (2018): <http://sinlist.chemsec.org/search/search?query=1309-64-4>, last viewed 19.04.2018

2. USE IN ELECTRICAL AND ELECTRONIC EQUIPMENT

The terms of references define the scope of the assessment on the application of diantimony trioxide to the use as flame retardant. Thus, a number of applications mentioned by stakeholders during the 1st stakeholder consultation²³ are out of scope of the assessment and will not be considered here.

2.1. Function of the substance

The function of ATO is that of a synergist for halogenated flame retardants. The International Antimony Association (i2a) (2018)²⁴ and the European manufacturer Campine, lead registrant for diantimony trioxide,²⁵ describes the function as flame retardant synergist as follows:

Diantimony trioxide (ATO) “is an additive which functions as a synergist with halogens, to confer high flame retardancy (and hence, fire safety) performance to plastic components used in EEE. Halogens provide flame retardancy via the so-called “Radical Trap Mechanism”. This is a process where reactive radicals are fed to the decomposition gas, which in turn cuts the supply of fuel [any substance that can combust, e.g. the plastic] to the combustion region, to cease the combustion chain reaction. The halogens released by the plastic they are contained in, quench the chemical reaction occurring in the flame by isolating the various factors, preventing the material from reaching its ignition temperature.

Whereas halogenated flame retardants are moderately effective on their own, they become twice more effective when combined with ATO (in a ratio of 1:3 or 1:4). ATO effectively enables a reduced use of halogens while increasing the flame retardancy of the plastics.[...] The use of a combined halogen + ATO flame retardant solution provides flame retardancy via an additional “Gas phase (heat absorption and dilution) Mechanism” of flame retardancy. The halogens with the ATO act as heat-absorbing substances which i) trigger endothermic reactions and cool down the polymer, and ii) dilute the decomposition gas and cut the supply of fuel to the combustion region, thereby ceasing the combustion chain reaction.”

²³ Use as clarifying aid in certain glasses, use as opacifying agent in functional ceramics and use as catalyst in the production of PET; see Appendix I for further explanation.

²⁴ International Antimony Association (i2a) (2018): Contribution submitted on 15.06.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15); http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_i2a_diantimony_Response_ATO_20180615_FINAL.pdf, last viewed 26.06.2018

²⁵ Campine (2018): Contribution submitted on 13.06.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15); http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_Campine_diantimony_response_ATO_180615_non_confidential.pdf, last viewed 26.06.2018

Fire safety standards

There are different fire safety standards with different tests worldwide and the requirements depend on the type of application / component.

Technical standards from the International Electrotechnical Commission (IEC) determine fire safety requirements; the IEC publications with the number 60695 (“IEC 60695 Series”) cover fire hazard testing issues, e.g. guidance for assessing the fire hazard of electro-technical products, glowing/hot-wire based test methods, etc.²⁶ There are also IEC test methods on the finished component depending on the end application, e.g. fire hazard testing on cables.²⁷

Besides the IEC standards, requirements from the American Underwriters Laboratories (UL) have been adopted in Europe and Asia as well. The UL-94 requirement is a test for flammability of materials; V-0 is the highest flammability rating.

Further standards according to i2a and Campine,²⁸ the “*Limiting Oxygen Index (LOI), which measures the minimum percentage of oxygen concentration it takes to support the candle-like or flaming combustion of plastics in an air-like gas mixture (ISO 4589 and ASTM D2863). Other methods include: Lateral Ignition and Flame spread Test (LIFT), upward flame spread tests (UL-94V and NASA 6001 test 1), cone calorimeter, Steiner Tunnel test (ASME E84)*”. However, the stakeholders Campine (2018) and i2a (2018) stress that UL 94 V-O is the most commonly referenced test in the E&E sector and indicates the highest flame-retardant level.

2.2. Types of applications / types of materials

Summarizing the stakeholder contributions, for the use of ATO as synergist for halogenated flame retardants in plastics, the following applications types can be differentiated in order to cover the waste stream of relevance:²⁹

1. Plastics used for enclosures and components,
2. Cables and wires and
3. Printed Wiring Boards (PWBs).

Plastics, e.g. for EEE enclosures

ATO is used in plastics for enclosures such as e.g. for telephone handsets, for keyboards, for monitors, housings for computer or TVs and for connectors, plugs and switches. Campine (2018) states that “*ATO will be present in levels between 2 and 8 % in flame retardant plastics.*” According to the Swedish Chemicals Agency KEMI (2015) “*levels up to 25 % [in plastics] are also observed.*”

²⁶ See the IEC page of the Technical Committee TC 89 Fire hazard testing at https://www.iec.ch/dyn/www/f?p=103:7:12958917783846:::FSP_ORG_ID,FSP_LANG_ID:1283,25, last viewed 14.05.2019

²⁷ https://www.iec.ch/dyn/www/f?p=103:7:0:::FSP_ORG_ID:1214, last viewed 14.05.2019

²⁸ Op. cit. International Antimony Association (i2a) (2018) and Campine (2018)

²⁹ Op. cit. Campine (2018), International Antimony Association (i2a) (2018), Europacable (2018), ZVEI (2018)

According to i2a, Acrylonitrile Butadiene Styrene (ABS) is a typical polymer where ATO is applied for enclosures. ZVEI states that aside from ABS, diantimony trioxide is used in Polytetramethylterephthalate plastics (PTMT) “and other plastics”.

To conclude, ATO is obviously used for enclosures in several types of plastics. The concentration of ATO is understood to vary, however, there were no backgrounds given for this variation, e.g. whether it depends on the flame retardant substance used.

Cables

Europacable (2018)³⁰ states that ATO is used in electric and optical cables for varying purposes, for different voltages and markets such as telecommunication, automation, construction, power networks, oil & gas, electrical appliances. As relevant for this assessment, europacable (2018) mentions the low voltage cables for electrical appliances.

Europacable (2018) further explains that the concentration of ATO in the homogeneous materials used in cable applications, in particular in sheath, due to its fire retardant property is higher than 0.1 %. Concentrations between 0.5 and 8 % have been identified.

As for polymers where ATO is added, europacable (2018) lists polyvinyl chloride (PVC) or polyethylene (PE) or rubber whereas i2a (2018)³¹ additionally lists polymethylpentane and polypropylene.

As for PVC as halogen-containing polymers, KEMI (2015) notes that no flame retardants need to be added. It is understood that the halogen content present in the PVC polymer sufficiently provides halogen compounds for ATO to react as synergist.

Printed Wiring Boards (PWBs)

According to the stakeholders, ATO is also used in PWBs together with brominated flame retardants (ZVEI 2018). According to Campine (2018), ATO is specifically used with tetrabromo bisphenol A (TBBP-A).

As for the polymer matrix for PWBs, the use of ATO can be expected as well, according to i2a e.g. in polymethyl pentane.

To conclude, it is understood that ATO is usually present in PWBs in the epoxy resins as well as potentially in other polymers.

2.3. Quantities of the substance used

There were no specific nor actual quantities provided by the stakeholders:

- i2a (2018) cites the quantity usage data for the EU compiled in the EU RAR from 2008³² with the reference year of 2005. The distribution of these quantities in the EU in 2005 was allocated to different materials that are relevant for the EEE sector as follows:

³⁰ Europacable (2018): Contribution submitted on 15.06.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15); http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_EUROPA_CABLE_Sb2O3_consultation_1_20180615.pdf, last viewed 26.06.2018

³¹ Op. cit. International Antimony Association (i2a) (2018)

- in (non-PVC) plastics: 9,200 tonnes,
- in PVC: 8,800 tonnes,
- in rubber: 2,200 tonnes.
- This results in about 20,000 tons of ATO in flame retardant plastic, resin and rubber that are placed on the EU market.
- For these 20,000 tonnes based in the amounts compiled in the EU RAR (2008), i2a³³ explains that single amounts can be allocated as follows:
 - 70 % is used in EEE plastics (i.e. max 14,000 t/a used in EEE (wiring boards and inner parts of EEE, cables, etc.).
 - 20 % in construction materials (insulation panels, insulation foamed films, film sheets and fabrics requiring flame retardancy, and cables) and
 - 10 % is used in other applications (e.g. insulation tapes in automotive sector) which are also not relevant for EEE.

Estimations for more recent years are provided by the Phosphorus, Inorganic and Nitrogen Flame Retardants Association PINFA (2017)³⁴ and Campine (2018), one of the registrants of ATO; however, both estimations are not EEE-specific: PINFA (2017) estimates the ATO consumption for the European market at approximately 20,000 tonnes in 2015,³⁵ whereas Campine³⁶ estimates that 10,000 tonnes ATO are used in Europe per year.

The above-stated amounts cannot be allocated to application types such as e.g. enclosures versus cables.

As for cables, Europacable (2018) states that no exact volume of ATO can be consolidated, as it is used in electrical and optical cable applications for various markets: telecom, automation, construction, power networks, oil & gas, electrical appliances. Europacable (2018) estimates that quantities in the range of 100 to 1000 tonnes of ATO are used for the EU cable market.

In conclusion, there is varying information on the amounts of diantimony trioxide. It is understood from this varying information that considerable amounts of ATO are used in EEE applications. It is further understood that mostly the information does not cover imported articles placed in the EU market. Therefore, a default value between the different numbers given would result in a substantial underestimation of ATO ending up in e-waste.

As most relevant applications for ATO, the following have been identified:

- Plastics for housings / enclosures,
- Cables,
- Printing Wiring Boards.

³² Op. cit. EU RAR (2008): European Union Risk Assessment Report. DIANTIMONY TRIOXIDE, November 2008

³³ Op. cit. International Antimony Association (i2a) (2018)

³⁴ Phosphorus, Inorganic and Nitrogen Flame Retardants Association PINFA (2017): Flame retardants in electric and electronic applications, non-halogenated phosphorus, inorganic and nitrogen (PIN) flame retardants; October 2017, 3rd edition; https://www.pinfa.eu/wp-content/uploads/2018/05/PINFA_EE_brochure_Edition_2017-11.pdf, last viewed 24.07.2018.

³⁵ ZVEI (2018) cited amounts given by the Phosphorus, Inorganic and Nitrogen Flame Retardants Association PINFA at 20,000 tonnes in 2015.

³⁶ Op. cit. Campine (2018)

Questions for stakeholders participating in the stakeholder consultation:

Specific information is requested to the ratio of ATO to the flame retardant, e.g. weight or volume ratio and specification of the flame retardants.

It should be further specified which halogenated flame retardant requires which concentration of ATO.

Specific information is requested on the concentration of ATO used in most relevant applications which are

- Plastics for housings / enclosures,
- Cables,
- Printing Wiring Boards.

Specific information is requested on the amount of ATO in the above listed applications. The amounts should at least include estimations on the total amount placed on the European market. The estimations should be detailed so that the numbers given can be followed.

3. HUMAN HEALTH HAZARD PROFILE

3.1. Endpoints of concern

Diantimony trioxide is classified for carcinogenicity Category 2 (H351 - Suspected of causing cancer) according to Annex VI of the CLP Regulation.

The Swedish Chemicals Agency KEMI (2015) summarized in its assessment of the risk reduction potential of hazardous substances in electrical and electronic equipment on the EU market: *“It has been agreed [this refers to e.g. the opinion of SCHER]³⁷ that the carcinogenic effects are most likely caused by particle overload and impaired lung clearance which leads to the formation of tumours (particle effect, no substance specific effect). ATO is considered a threshold carcinogen with an NOEL of 0.5 mg/m³ (with the critical concentration expected to be 10 times higher). The carcinogenic hazard by inhalation does not apply via dermal or oral exposure.”*

This hazard based on particle effect is also described by Campine:³⁸ *“Fine dust inhalation leads to lung overload and lung toxicity, which has triggered a carcinogenic response in certain test animals through inflammation and hypoxia (NTP)”*

The Canadian Ministers of the Environment and of Health have conducted a screening assessment of diantimony trioxide in 2010 concluding that there is no evidence available to suggest carcinogenic potential for antimony trioxide via the oral route.

In the EU RAR³⁹, it was concluded that diantimony trioxide is of low acute toxicity via oral and dermal route. As for the repeated dose toxicity; the EU RAR stated that the studies *“indicate that*

³⁷ Scientific Committee on Health and Environmental Risks SCHER (2010/2011): Opinion on the Risk from the Use of Diantimony Trioxide in Toys; https://ec.europa.eu/health/scientific_committees/environmental_risks/docs/scher_o_125.pdf (last viewed 24.07.2019)

³⁸ Op. cit. Campine (2018) and Annex 1 of the contribution submitted by Campine (2018); http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_Campine_diantimony_Annex_1.pdf, last viewed 28.06.2018

³⁹ Op. cit. EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

repeated inhalation exposure to diantimony trioxide may cause pulmonary inflammation, lung emphysema and pneumoconiosis.”

As for mutagenicity, in the EU RAR it is explained that *“diantimony trioxide does not cause systemic mutagenicity in vivo after oral administration. However, it is not possible to conclude on mutagenicity in specific site of contact tissues (local mutagenicity) and thus, whether the result is relevant for the situation in the lung after inhalation exposure, which is the site where tumours have been found in the carcinogenicity studies. However, the in vivo data might suggest that a possible mutagenic potency of diantimony trioxide would be low and it is believed that a possible local genotoxic effect of diantimony trioxide would only be biologically relevant at concentration levels that also cause particle overload.”*

Collective evidence from genotoxicity studies suggests that antimony trioxide is not likely to be mutagenic but may exert some clastogenic effects in vitro. (Canada 2010) noted the clastogenic effect in vitro and independently decided that no conclusive in vivo evidence of genotoxicity was available for antimony trioxide.

According to the Swedish Chemical Agency KEMI (2015), also reprotoxic effects have been reported. However, the little number of studies suggesting reprotoxic effects are at least so far not substantial enough to for a further in-depth assessment and classification.

Additionally, one in vitro study on bacteria and mammal cells from 2009 indicated that ATO was genotoxic.⁴⁰

To conclude, ATO is considered being suspected of causing cancer via inhalation; furthermore, the carcinogenic effect observed in the lung is considered a particle effect. Thus, inhalation is the exposure route where a focus should lie. In contrast, carcinogenicity is not considered to apply to dermal and oral exposure.

3.2. Existing Guidance values (DNELs, OELs)

Occupational exposure limits

There are occupational exposure limits established in several EU countries at 0.5 mg/m³ antimony trioxide, however some even lower. The table below shows the international limit values as compiled by IFA, the institute for occupational safety from the German Social Accident Insurance in the database GESTIS International Limit Values.⁴¹ In Germany, the occupational limit value was lowered to 6 µg Sb/m³ for the respirable fraction in May 2018.⁴²

The Swedish Chemicals Agency KEMI recommended in 2008⁴³ to establish occupational exposure limit values for antimony trioxide according to Directive 98/24/EEC on the protection of the health and safety of workers from the risks related to chemical agents at work. However, a European wide coherent OEL has not been set so far.

⁴⁰ Op. cit. Swedish Chemical Agency KEMI (2015)

⁴¹ IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung; GESTIS International Limit Values: Entry for Antimony trioxide; https://limitvalue.ifa.dguv.de/WebForm_ueliste2.aspx

⁴² Ausschuss für Gefahrstoffe – AGS, BAuA (2018): Begründung zu Antimontrioxid und Antimontrisulfid (A-Staub) in TRGS 900, Ausgabe: Mai 2018; https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/pdf/900/900-antimontrioxid-antimontrisulfid.pdf?__blob=publicationFile&v=2

⁴³ Swedish Chemicals Agency (2008): Proposal for Community-wide measures to reduce risks; Diantimony Trioxide; 2008-11-26; http://www.echa.europa.eu/documents/10162/13630/trd_sweden_diantimony_trioxide_en.pdf, last viewed 19.04.2018

Table 3-1: International limit values for ATO provided by IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung in GESTIS International Limit Values

Country	Limit value - Eight hours, mg/m ³
Australia	0,5
Austria	0,1
Canada - Québec	0,5
Finland	0,5
Germany (AGS)	0,006
Hungary	0,1
Latvia	1
New Zealand	0,5
Singapore	0,5
South Korea	0,5
Sweden	0,25
Switzerland	0,1
United Kingdom	0,5

Source: GESTIS International Limit Values: Entry for Antimony trioxide

Values submitted during REACH registration

The following guidance values have been submitted by the industry as part of the REACH registration dossiers. These values are not verified by official authorities. The DNELs for diantimony trioxide as summarised on the ECHA information on chemical database which come from Registration dossiers (i.e. from industry) are compiled in Table 3-2. Exposure routes where no hazard was identified are not listed here.

Table 3-2: Guidance values for diantimony trioxide, bw = body weight

Population	Local / systemic effect	Effects	DNEL
Workers	Inhalation Exposure	Local Effect - Long term	315 µg/m ³
	Dermal Exposure	Systemic Effect - Long term	67 mg/kg bw/day
General Population	Inhalation Exposure	Local Effect - Long term	95 µg/m ³
	Dermal Exposure	Systemic Effect Long term	33.5 mg/kg bw/day
	Oral Exposure	Systemic Effect Long term	33.5 mg/kg bw/day

Source: ECHA Brief Profile: Entry for Diantimony trioxide

To conclude on the human health hazards, the carcinogenic hazard of ATO by inhalation is the exposure route that might also be relevant in the waste phase due to waste management operations with size reduction. The occupational exposure limits will be taken as guiding values for inhalation. As for dermal exposure, the DNEL provided by the registrants will be taken into account.

4. ENVIRONMENTAL HEALTH HAZARD PROFILE

The Canadian Ministries of the Environment and of Health conducted a screening assessment of diantimony trioxide in 2010. This is the most recent environmental assessment publically available for diantimony trioxide. For environmental effects, the assessment is mainly based on information on the acute and chronic toxicity of dissolved antimony to a variety of aquatic, soil and sediment organisms compiled in the EU RAR (2008).

As for the environmental fate, the Canadian Ministries of the Environment and of Health⁴⁴ summarize that diantimony trioxide has some (though limited) solubility in water and will therefore dissolve in contact with moisture once in these ecosystems and yield a variety of dissolved antimony species, depending on the environmental conditions. Given its negligible vapour pressure and limited water solubility, antimony trioxide will tend to remain in soil rather than migrate into other environmental media, such as air or water.⁴⁵

The transformation of diantimony trioxide in the different environmental compartments is rather complex as described in the EU RAR (2008)⁴⁶. The appearance of different binding/speciation forms and oxidation states of antimony depends on the pH, the presence of other metal ions or on oxic versus anoxic systems for sediments and soil.

Regarding potential PBT properties, the European approach as laid down in REACH Annex XIII defines that the PBT and vPvB criteria only apply to organic substances, including organo-metals. However, the Canadian Ministries of the Environment and of Health⁴⁷ consider the substance diantimony trioxide as being persistent because the trivalent antimony ions that are released into solution when it dissolves cannot be irreversibly degraded. Depending upon ambient conditions, e.g. pH, trivalent antimony can be oxidized to pentavalent antimony. This transformation is typically reversible. Therefore, the Canadian Ministers of the Environment and of Health⁴⁸ conclude that antimony trioxide meets the persistence criteria for all media (i.e., air, water, soil and sediment).

To conclude, potential releases of ATO from EEE manufacturing and use would dissolve in the environment and would be part of dissolved antimony species found in the environment.

⁴⁴ Op. cit. Environment Canada, Health Canada (2010)

⁴⁵ Environment Canada, Health Canada (2010): Screening Assessment for the Challenge Antimony trioxide (Antimony oxide) Chemical Abstracts Service Registry Number 1309-64-4; September 2010; https://www.ec.gc.ca/ese-ees/9889ABB5-3396-435B-8428-F270074EA2A7/batch9_1309-64-4_en.pdf, last viewed 19.04.2018

⁴⁶ Op. cit. EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

⁴⁷ Op. cit. Environment Canada, Health Canada (2010)

⁴⁸ Op. cit. Environment Canada, Health Canada (2010)

4.1. Endpoints of concern

The Canadian Ministries of the Environment and of Health⁴⁹ conclude that the data indicate that soluble forms of antimony generally have a moderate potential to cause harm to aquatic, soil and sediment organisms.

There are companies notifying self-classifications, so called notifiers, that classify diantimony trioxide for being hazardous to the aquatic environment (Aquatic Acute 3 - H412, Harmful to aquatic life with long lasting effect), among them a joint submission of a REACH registrations dossier.

According to the above mentioned, there is clear evidence that antimony and its compounds have adverse effects on aquatic life, which should be taken into account if exposure to the environment will be looked at.

4.2. Potential for secondary poisoning and bioaccumulation

The Canadian assessment explains that for metals, bioaccumulation determined by a bioconcentration factor (BCF) or a bioaccumulation factor (BAF) is considered of little usefulness:

“For example, some metals may be highly accumulated from the surrounding medium because of their nutritional essentiality. Furthermore, both essential and non-essential metals may be regulated within relatively narrow margins by the homeostatic and detoxification mechanisms that many organisms possess. It follows that when ambient concentrations of metals are low, BCFs and BAFs often increase. Conversely, when ambient metal concentrations are high, BCFs and BAFs tend to decrease [...]. Thus, inverse relationships may be observed between BCF and BAF values and metal exposure concentrations, and this complicates the interpretation of these values. Natural background concentrations in organisms may contribute to these negative trends. [...]

Although field-based BAFs can give some indication of the biomagnification potential of a metal, a better approach is to derive a trophic transfer factor from prey to predator [...] (also called trophic magnification factor or TMF), or to study changes in metal concentrations in biota making up natural food webs (i.e., trophic magnification).”

In the assessment of Environment Canada, Health Canada (2010), it is concluded that there are several lines of evidence to suggest that the bioaccumulation potential of antimony in natural ecosystems is low: *“very low BCFs and BAFs obtained from three laboratory (steady-state) studies and three field studies, three biota–soil accumulation factors well below 1, and two field investigations indicating the absence of biomagnification of antimony in natural food webs.”*

In the EU RAR,⁵⁰ it is concluded for bioaccumulation that no fully reliable bioaccumulation studies are available and measured data from different aquatic organisms have been used to calculate tentative BCF-values:

- For marine fish the BCFs vary between 40 and 15,000 whereas for freshwater fish the BCF values are lower the highest being 14.
- For invertebrates tentative BCFs in the range of 4,000-5,000 have been calculated.

⁴⁹ Op. cit. Environment Canada, Health Canada (2010)

⁵⁰ Op. cit. EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

According to the EU RAR, there is a considerable uncertainty in these BCF-values. The risk characterization for secondary poisoning in the EU RAR was performed using two BCF values of 40 and of 15,000. In the EU RAR a $PNEC_{sec\ poisoning}$ was determined of 374.8 mg Sb/kg food and also for secondary poisoning in the marine environment.

Potential for secondary poisoning and bioaccumulation will not further be considered because as diantimony trioxide will solubilize in water and transform into antimony ions, it is considered that the allocation of the respective antimony compounds cannot be determined.

4.3. Guidance values (PNECs)

The predicted no effect concentration (PNEC) is the concentration below which exposure to a substance is not expected to cause adverse effects to species in the environment. Therefore, the determination of these values is important for further characterisation of possible risks.

The PNECs from the EU RAR are compared to the PNEC values extracted from the REACH registration dossiers as shown in the ECHA information on chemicals database.⁵¹

Table 4-1: PNECs of diantimony trioxide

	Compartment	PNEC values EU RAR	PNEC value Registration dossiers
Hazard for Aquatic Organisms	Freshwater	113 µg Sb/l	135 µg/L
	Marine water	11.3 µg Sb/l	13.5 µg/L
	Sewage treatment plant (STP)	2.55 mg Sb/l	3.05 mg/L
	Sediment (freshwater)	11.2 mg Sb/kg dw	13.4 mg/kg sediment dw
	Sediment (marine water)	2.24 mg Sb/kg dw	2.68 mg/kg sediment dw
Hazard for Terrestrial Organism	Soil	37 mg Sb/kg dw	44.3 mg/kg soil dw

Source: European Chemicals Agency ECHA, Brief Profile: Entry for Diantimony trioxide, <https://echa.europa.eu>, and EU RAR (2008)

If guidance values will be needed in the following assessment, the PNEC values from the EU RAR will be taken. The PNEC values provided in the registration dossier is considered not to have been subject to scrutiny by ECHA or any EU expert group.

5. WASTE MANAGEMENT OF ELECTRICAL AND ELECTRONIC EQUIPMENT

5.1. Description of waste streams

Enclosures: Plastics

The WEEE Directive⁵² requires that plastics used in EEE containing brominated flame-retardants have to be removed from any separately collected WEEE according to Annex VII on the selective

⁵¹ <https://echa.europa.eu/de/brief-profile/-/briefprofile/100.013.796>

treatment for materials and components of waste electrical and electronic equipment referred to in Article 8(2).

ATO is stated to be used as synergist together with halogenated flame retardants and, specifically in plastics, with brominated flame retardants. The separation process of brominated flame retardants as applied in Europe is established on density based sink-float sorting techniques after size reduction by shredding. Post-shredder sorting techniques separate plastics that contain a diantimony trioxide-based flame retardant combination with a high efficiency from other non-flame retardant plastic types, because of the high density of antimony trioxide ($\rho = 5,7 \text{ g/cm}^3$).⁵³ According to the KU Leuven,⁵⁴ X-ray fluorescent based optical sorting techniques are also used alternatively or in combination with density based sink-float sorting techniques after size reduction by shredding as state of the art recycling processes in Europe.

This fraction is as of today's state of the art not recycled but sent to incineration with energy recovery as there is no further post-shredder sorting of different plastic materials to obtain a required purity, e.g. to separate the plastic material ABS and HIPS containing brominated flame retardants.

As for the recovery of antimony from the ashes of the incinerated plastics, it is so far not common practice according to the KU Leuven. Campine (2018) also states that *"the recovery of antimony out of plastics is not yet implemented on a broader scale because the operation is not economically viable yet and rather complex (due to pop's in FR plastics)."* i2a (2018) explains that *"in a number of countries, bottom ash is used for road and other constructions, unless the concentration of ATO in the ash exceeds a particular limit, in which case it must be treated as a hazardous waste (i.e. landfilled)."*

Printed Wiring Boards and their resins

Printed wiring boards that contain brominated flame retardants and diantimony trioxide are usually treated by copper smelters to recover the copper. The plastic material is sent to incineration with energy recovery.⁵⁵

The printed wiring boards are taken out before shredding, because there are typically established recycling routes for these, aimed to recover the precious and minor/rare metals they contain.⁵⁶

⁵² Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast); <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN>, last viewed 02.07.2018

⁵³ KU Leuven-University of Leuven (2018): Contribution submitted by Jef Peeters, Department of Mechanical Engineering, Faculty of Engineering & Engineering Technology, KU Leuven-University of Leuven on 15.06.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15); http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/Contribution_KU_LEUVEN_Diantimony_Trioxide_20180615.pdf, last viewed 26.06.2018 and Op. cit. ZVEI (2018)

⁵⁴ Op. cit. KU Leuven-University of Leuven (2018)

⁵⁵ Op. cit. ZVEI (2018)

⁵⁶ Op. cit. Campine (2018)

Cables

PVC cables that might also contain diantimony trioxide are usually first separated from WEEE and then recycled separately.⁵⁷

The cables can be stripped or they can be shredded in whole. In both methods, the plastic mantle can be recuperated (e.g. by density sorting).⁵⁸

Europacable specifies (2018):⁵⁹

The usual process for cables treatment at end of life is

- i. A sorting per cable type/materials (PVC or PE or rubber or...)
- ii. Per cable lot (for instance PVC based), a grinding of the cable and a plastic/metal separation thanks to vibrating tables

The cables specifically containing ATO, for instance based on PVC, are not separated from the other PVC cables stream. They are all grinded together and the PVC obtained after treatment may most probably contain ATO at variable concentration. A recycling takes place at least in some front running companies,⁶⁰ however, the share of the recycling of cable insulation compared to the total amount of cable material / insulation has not been indicated by industry.

5.1.1. Main materials in the waste stream where the substance is contained

From the above, it can be understood that ATO in the waste phase shall mainly be contained in polymer plastics from housings and cables (e.g., ABS, PVC, PE) as well as in PWB laminates.

5.1.2. WEEE categories containing the substance

ATO is used for the flame retardancy of plastics in housings, cables and electric installations as well as of laminates for PWB. These materials and components are found in almost all types of EEE: Plastic housings are also quite common, particularly but not exclusively in consumer products that do not require the robustness provided by metal housings. It is thus expected that relevant components and materials can be found in EEE of all categories.

⁵⁷ Op. cit. ZVEI (2018)

⁵⁸ Op. cit. Campine (2018)

⁵⁹ Op. cit. Europacable (2018)

⁶⁰ E.g. as mentioned by Campine (2018):

CABLO, a subsidiary of the Aurubis Group, is specialized in the separation of metals and plastics, in particular in the recycling of cable waste and cable scrap. In addition to recovering brass, aluminium, copper, iron and lead, CABLO re-uses the plastic components using an injection moulding technique which has been specially developed to recycle plastics (PVC, PE).

The Vinyloop© process developed by Solvay is a mechanical recycling process using an organic solvent to separate the PVC compound from other types of plastic waste or from the other materials in a PVC composite.

The tonnage of recycled cables is increasing due to direct reuse of PVC and recycling via the Vinyloop process. In 2016, 127 kTon of PVC cables were recycled (containing ATO).

5.2. Applied waste treatment processes

5.2.1. Initial treatment processes applied to the WEEE containing the substance of concern

The following table summarizes in which initial treatment processes ATO-containing materials of EEE can be found. Collection and transport are also relevant for all WEEE categories collected separately but is not considered for potential emission of ATO in this process. Whereas manual dismantling is not relevant for all (W)EEE categories, the treatment process shredding (and automated sorting) is relevant for all EEE categories. This process, where mechanical disintegration and crushing of the appliances (various types of shredding, grinding processes etc.) takes place, should be further assessed for potential emissions of ATO.

Table 5-1: Initial treatment processes applied

Initial treatment processes	The substance is present in appliances belonging to:										
	Cat 1: Large household appliances	Cat 2: Small household appliances	Cat 3: IT and telecommunications	Cat 4: consumer equipment	Cat 5: Lighting equipment	Cat 6: Electrical and electronic tools	Cat 7: Toys leisure and sports equipment	Cat 8: Medical devices	Cat 9: Monitoring and control instruments	Cat 10: Automatic dispensers	Cat 11: Other EEE not covered by categories 1-10
For WEEE collected separately											
Collection and transport	x	x	x	x	x	x	x	x	x	x	x
Dedicated treatment processes for cooling & freezing appliances	x										
Dedicated treatment processes for screens	x	x	x			x	x	x	x		x
Dedicated treatment processes for lamps					x						
Manual dismantling (also for refurbishment)	x	x	x	x	x	x		x	x		
Shredding (and automated sorting)	x	x	x	x	x	x	x	x	x	x	x
For WEEE not collected separately											
Landfilling (of residual waste)		x	x		x	x					
Mechanical treatment (of residual waste)		x	x		x	x					
Incineration	x	x	x	x	x	x	x	x	x	x	x
Uncontrolled treatment in third countries	x	x	x	x	x	x	x	x	x	x	x

5.2.2. Treatment processes applied to wastes derived from WEEE containing the substance of concern

The following table summarises the treatment processes of secondary waste derived from WEEE treatment.

Table 5-2: Treatment processes for wastes derived from WEEE

Treatment processes for wastes derived from WEEE treatment	The substance is present in the following main component/material								
	Ferrous metals	Non-ferrous metals	Plastics	Electronic components	Cables	Glass	Powders	Fluids	Others
Under current operational conditions in the EU									
Storage of secondary wastes									
Shredding and automated sorting of secondary wastes			x	x	x				x
Recycling of ferrous metals									
Recycling of NF metals									
Recycling of plastics			x	x	x				x
Recycling of glass									
Recycling as building material									
Landfilling of residues			x	x	x				
Incineration of residues			x	x	x				x
Co-incineration of residues			x	x	x				x
Dedicated processes for hazardous residues			(x)	(x)	(x)				(x)
Under uncontrolled conditions									
Acid leaching									
Grilling/desoldering									
Uncontrolled combustion			x	x	x				
Uncontrolled dumping of residues			x	x	x				x

5.3. Waste treatment processes relevant for assessment under RoHS

As presented above, the main waste treatment processes in which ATO can be expected to be present include:

- All relevant materials/components: Collection and sorting of WEEE (PWBs and cables are sorted out and sent to separate treatment);
- Plastic casing: Shredding of WEEE followed by sorting of shredded fraction:
 - Density based sink-float sorting techniques, to separate plastics containing BFR from shredded fraction (more common);

- Sorting techniques based on x-ray fluorescence which detects bromine content (BFRs), to separate plastics containing BFR from shredded fraction (less common);
- PWBs – Copper smelting is performed on PWBs to recover the copper, sending residual plastic including ATO as part of flame retardant materials to incineration and thermal recovery;
- Cables are treated separately:
 - Cable types are sorted to various groups (PVC, PE, rubber, etc.);
 - Plastic and metal are separated through stripping/shredding grinding;
 - This is followed by sorting with vibration tables or density sorting so as to recuperate the plastic mantle (density sorting);
 - A mechanical separation process which is solvent-based has also been developed (Vinyloop©) to separate PVC compounds from other plastic waste and from other PVC composites to allow reuse of PVC. This is understood to be a new process still implemented on small scale compared to the total amount of EEE cables placed on the market.
- Incineration with energy recovery of WEEE residues/separated fraction containing ATO as part of flame retardant system;
- Recovery of antimony from the ashes of the incinerated plastics and other components is currently not common, but applied in some countries (where ATO concentration is above a certain limit, fraction is treated as hazardous waste, i.e. landfilled).

5.4. Releases from (relevant) WEEE treatment processes

From the waste treatment processes mentioned above, the shredding processes are the most relevant concerning releases of substances incorporated in the shredded material. During shredding processes, the material is mechanically highly worked-up and dust is released. Substances like ATO may occur being bound to the airborne particles resulting from the shredding of the material. The emissions to air are considered rather relevant for human health (workers) and will therefore be further evaluated in the exposure estimations. Through the treatment of ATO-containing WEEE articles and the deposition of airborne particles, the substance evaluated here ends up in other environmental compartments like water and soil (waste water, ...).

5.4.1. Releases to air, water and soil from waste incineration plants

KEMI (2015) refers to possible emissions from incineration: *“Incineration of plastic waste from EEE products can produce discharges of antimony trioxide distributed among various output fractions, such as emissions, wastewater, ash and slag. Previous studies estimated concentrations of antimony in municipal waste to approximately 10-60 ppm, with large variations. From EEE waste, the concentrations are reported to be in the range from several hundred up to thousands ppm.”*

In the EU RAR (2008), emission estimations for incineration are made for Municipal Solid Waste (MSW) assuming a concentration value of antimony of 40 mg Sb/kg waste (= 40 ppm). However, KEMI (2015) stated that from EEE waste, the concentrations are reported to range from several hundred up to thousands ppm.

Emissions from incineration plants are expected via air, wastewater, ash and slag.

The EU RAR rapporteur assumed 1 % emissions to air and 0.3 % emissions to water. 60 % of the antimony in the influent incinerator wastewater is removed as sludge and 40 % remains in the

wastewater and will be released to the waste water treatment plant (WWTP). The sludge generated goes to a hazardous waste landfill.

Tabelle 5-1: Total annual amount of antimony emissions to air, water and landfill due to 100 % incineration of MSW within the EU

Compartment	Released amount of antimony (t/y)	Continental (90 %; t/y)	Regional (10 %; t/y)
Air	4.5	4.0	0.4
Wastewater	5.4	4.9	0.5
Landfill (ash + sludge)	4,485	4,037	448

Quelle: EU RAR (2008)

As long as the activities related to a specific stage of the life-cycle of a substance can be assumed to take place within a region, as it is often the case for manufacture, formulation and industrial uses, 100 % of the whole registrant's tonnage at EU level is attributed to the regional scale. When activities are more widely distributed over the EU, as is assumed for wide dispersive uses or in this case incineration, only a fraction of the whole registrant's tonnage at EU level is attributed to the region (10 % by default) while most of it (90 % by default) is attributed to the continental scale.⁶¹

It is obvious that plastic waste containing halogenated flame retardants contains a higher amount of ATO. Therefore, these emission estimations are not comparable to WEEE ATO plastic waste. Nonetheless, not all WEEE is properly disposed of by consumers and thus collection rates in the EU are far from 100 %. WEEE that is not properly collected shall at least in part be sent to municipal treatment for which the values above are considered to be representative.

⁶¹ ECHA (2016): Guidance on information requirements and Chemical Safety Assessment Chapter R.16: Environmental exposure assessment; Version 3.0, February 2016; https://echa.europa.eu/documents/10162/13632/information_requirements_r16_en.pdf, last viewed 24.07.2018

6. EXPOSURE ESTIMATION DURING USE AND DURING WEEE TREATMENT

For exposure estimations, the following scenarios will be looked at:

- WEEE treatment and therein the shredding process of EEE plastics;
- Incineration of waste fractions;
- General release of ATO into the environment.

6.1. Human exposure estimation

6.1.1. Exposure of workers of EEE waste processing plants

From the description of the waste streams it is assumed that exposure of workers in WEEE waste processing plants to diantimony trioxide can occur during the processes of processing and shredding cable and plastic waste, where generation of dust from decomposing and shredding of EEE plastic is likely.

Exposure can occur through inhalation of dust and dermal uptake, whereas the exposure through inhalation is assumed to be the relevant exposure pathway.

Exposure estimation for workers was modelled by using the ECETOC's Targeted Risk Assessment (TRA)⁶² tool to calculate the risk of exposure from chemicals to workers, consumers and the environment. The ECETOC TRA tool is intended for manufacturing and formulation processes. Hence, appropriate processes to describe the exposure conditions of waste treatment processes do not yet exist.

However, process category 24: "high (mechanical) energy work-up of substances bound in materials and/or articles" has been selected to calculate the exposure of workers of EEE waste processing plants. This approach was first introduced by the Austrian Umweltbundesamt for the RoHS assessment of the phthalates DEHP, DBP and BBP⁶³ and has also been used by KEMI for the MCCP dossier⁶⁴ and the Fraunhofer Institutes for the assessment of TBBP-A that has been performed on behalf of the BSEF, aisbl – The International Bromine Council and was submitted as part of the contribution of BSEF on 23.04.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 in the course of this study.⁶⁵

⁶² <http://www.ecetoc.org/tools/targeted-risk-assessment-tra/>

⁶³ <https://www.umweltbundesamt.at/rohs2>

⁶⁴ Swedish Chemicals Agency KEMI (2018): ROHS Annex II Dossier MCCP, Proposal for a restriction of a substance in electrical and electronic equipment under RoHS; <https://www.kemi.se/global/rappporter/2018/report-4-18-rohs-annex-ii-dossier-mccp.pdf>, last viewed 24.07.2018

⁶⁵ The following assessment was submitted as part of the contribution of BSEF, aisbl – The International Bromine Council: Contributions submitted on 23.04.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15); see PDF5 at: <https://rohs.exemptions.oeko.info/index.php?id=291>:

Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM), Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) (n.y.): Assessment of TBBPA (tetrabromobisphenol A) according to the "Methodology for Identification and Assessment of Substances for Inclusion in the List of Restricted Substances (Annex III) under the RoHS2 Directive"; submitted as contribution of the BSEF, aisbl – The International Bromine Council to the 1st stakeholder consultation, submitted on 23.04.2018; available at:

As ATO is a metalloid-containing inorganic substance, exposure estimation based on (the very low) vapour pressure is not applicable. Instead, the exposure estimation for ATO as a solid was modelled. Further selected input parameters for the plastic and cable shredding were taken in accordance with other RoHS assessments (KEMI 2018, Austrian Umweltbundesamt and Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM), Fraunhofer Institute for Manufacturing Engineering and Automation (FhG-IPA):

- professional setting,
- 8 hours activity (>than 4 hours),
- outdoors, since shredding equipment is assumed to be either completely outdoors or in large, partially open halls,
- no respiratory protection or gloves (dermal PPE - personal protective equipment).

As for the parameter in substance in the preparation, the range of 1 to 5 % was chosen based on the information on the applications of ATO in plastics and cables (see section 2.3).

Measurements in the plastic waste stream supports the assumption that this range is realistic: Morf and Taverna (2004)⁶⁶ measured in TV and PC enclosures a content of 1.6 % antimony, and a more recent measurement in plastic fraction of WEEE revealed a content of 1.4 % antimony.⁶⁷

The input parameters for the exposure estimation are compiled in Table 6-1.

Table 6-1: Input parameters used in ECETOC TRA for worker exposure

Scenario name	Shredding of WEEE plastic and cables
Treatment setting	Professional
Duration of activity	>4 hours/day
Use of ventilation	Outdoors
Respiratory protection	No
Substance in preparation	1-5 %

Source: Own compilation based on ECETOC TRA 3.1

In ECETOC TRA, the process category 24 (PROC 24) described as “high (mechanical) energy work-up of substances bound in materials and/or articles” and the subcategory assuming a low fugacity leads to the following exposure values, concentrations are given in mg/m³:

https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_15/1st_Consultation_Contributions/TBBPA_und_RoHS_13102015_clean__2_.pdf

⁶⁶ Morf, L. & Taverna, R. (2004): Metallische und nichtmetallische Stoffe im Elektroschrott, Stoffflussanalyse.

⁶⁷ Taverna, R. et al. (2017): Stoffflüsse im Schweizer Elektronikschrott. Metalle, Nichtmetalle, Flammschutzmittel und polychlorierte Biphenyle in elektrischen und elektronischen Kleingeräten. Bundesamt für Umwelt, Bern. Umwelt-Zustand Nr.1717; <https://www.bafu.admin.ch/bafu/de/home/themen/chemikalien/publikationen-studien/publikationen/stofffluesse-im-schweizer-elektronikschrott.html>

Table 6-2: Exposure estimates with ECETOC TRA for ATO in PROC 24a

Process Category (PROC)	Long-term Inhalative Exposure Estimate (mg/m ³)	Long-term Dermal Exposure Estimate (mg/kg/day)
	c= 1-5 %	c= 1 – 5 %
PROC 24a	4,20E-01	5,66E-01

Source: Own compilation based on ECETOC TRA 3.1

The estimations yielded with ECETOC TRA are based on rather conservative assumptions. In order to further evaluate the estimates, workplace measurements have been investigated in other studies. However, there are few measured values for ATO from workplaces in the waste management sector:

The institute for occupational safety from the German Social Accident Insurance⁶⁸ carried out a statistical evaluation for workplace measurements for antimony and its compounds other than hydrogen antimony in the period from January 2005 to May 2017. From this evaluation, it is understood that in the sector of “waste disposal and incineration, slag processing, electrical scrap recycling, wholesale with scrap material”, 43 measurements from the workplace are available; thereof 37 % were below the detection limit of 0,0075 mg/m³ and 95 % of the measurements revealed levels below 0,011mg/m³ (detection limit plus 0,00346). Thus, there is a great difference between the estimated and measured data from Germany. The German Federal Institute for Occupational Safety and Health BAuA, as the member state authority for ATO in the CORAP list⁶⁹, was asked to provide more data.

One occupational exposure study in e-waste recycling plants in Sweden⁷⁰ examined the workers' exposure to metals. Samples were taken for recycling workers by personal air samplers and for office workers by static sampling at three formal e-waste recycling plants in Sweden. The measured concentrations in the inhalable⁷¹ as well as the OFC⁷² fraction are compiled in the following table. In general, the data meets the expectation of a higher exposure for recycling workers than for office workers. The geometric mean concentration for antimony in the inhalable fraction was ~25 times and ~6 times higher for the recyclers than for the office workers, respectively.

⁶⁸ IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (n.y.): MEGA-Auswertungen zur Erstellung von REACH-Expositionsszenarien für Diantimontrioxid sowie Antimon und seine Verbindungen, außer Antimonwasserstoff; https://www.dguv.de/medien/ifa/de/fac/reach/mega_auswertungen/antimon.pdf

⁶⁹ Op. cit. BAuA (2016)

⁷⁰ Julander, A; Lundgren, L.; Skare, L.; Grandér M.; Palma, B.; Vahter, M.; Lidéna, C. (2014): Formal recycling of e-waste leads to increased exposure to toxic metals: An occupational exposure study from Sweden; Environment International 73 (2014) 243–251.

⁷¹ Inhalable fraction: “Mass of total airborne particles that is inhaled through the nose and mouth.” (International Organization for Standardization, 2012)

⁷² Open face cassette (OFC) 37-mm cassette sampler for collecting airborne particles corresponding to OELV (occupational exposure limit values). Has been called total dust sampler.

Table 6-3: Antimony concentration (GM (GSD) & range) in the collected inhalable fraction and OFC fraction from personal air sampling (exposure data for recycling workers) and from static sampling (exposure data for office workers) at three e-waste recycling plants in Sweden

	Inhalable fraction (µg/m ³)		OFC fraction (µg/m ³)	
	Recycling workers (n=77)	Office workers (n=3)	Recycling workers (n=65)	Office workers (n=3)
GM (GSD)	0.21 (2.3)	0.0085 (2.0)	0.15 (2.5)	0.023 (2.9)
range	0.0041–1.1	0.0041–0.015	0.0042–0.88	0.011–0.049

Source: Julander et al. 2014

Note: GM – Geometric Mean, GSD – Geometric Standard Deviation

Julander et al. (2014) also analysed biomarkers from workers and found linear correlations for antimony between the inhalable fraction and exposure biomarkers (blood, plasma and urine) as for some other metals such as e.g. mercury and lead. Thus Julander et al. (2014) point out the occupational exposure to multiple metals for e-waste recycling work, even in modern plants with adequate protection routines, and claim that rare metals such as In and Sb, and not only Hg and Pb, must be monitored in these settings both in air and human samples. It has to be noted that the exposure by multiple toxic metals as a combined/cumulative exposure cannot be considered here.

To conclude, the exposure estimations gained in ECETOC TRA are more than a thousand times higher than exposures measured at working places in the study of Julander et al. (2014). The data from the working places indicate that the strictest occupational exposure limits in the EU of 6 µg/m³ are not exceeded.

However, it is not known whether the workplaces examined by Julander et al. (2014) have different protection routines than other facilities in the EU.

6.1.2. Exposure of neighbouring residents of EEE waste processing plants

From the EU, no data have been found on the exposure of neighbouring residents of EEE waste processing plants. It is understood that for the incineration of plastic waste from EEE products, the IED Directive 2010/75/EU⁷³ on industrial emissions (integrated pollution prevention and control) applies where the air emission limit values for waste incineration plants for antimony and its compounds are set at 0,5 mg/m³ for antimony and its compounds, expressed as antimony (Sb). It is understood that the IED Directive covers the potentially relevant emissions from waste incineration plants. Thus, this exposure will not be further considered here.

⁷³ Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast); <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN>, last viewed 24.07.2018

6.1.3. Consumer exposure

According to the EU RAR,⁷⁴ diantimony trioxide is used in several products available to consumers which are PET, flat and pile upholstered furniture (residential and commercial furniture), cuddly toys, upholstery seatings and automobile interior textiles in private and public transportation, draperies, and wall coverings, electrical and electronic equipment e.g. distribution boxes for electrical lines and polyvinyl chloride wire, cable and textile coating.

The EU RAR states that *“the release of diantimony trioxide from the surface of products to atmospheres may be a potential way of exposure. Due to negligible volatility of diantimony trioxide, vapour release is not relevant. Instead, diantimony trioxide may be released as dust due to wear or abrasion. Direct dermal contact with products containing diantimony trioxide may give dermal exposure.”*

Among the scenarios presented in the EU RAR (“drinking from a PET-bottle”, “sucking on cuddly toys” (oral exposure), “indoor air” (inhalation and oral exposure) and “sitting on upholstery fabric” (dermal exposure)), the scenario on indoor air is the relevant one for EEE. Relating to inhalation exposure, the scenario based on values measured in a study on the ATO content in household dust conducted in the UK stated: *“Compared to naturally occurring amounts in soil of around 0.2 µg/g, house-dust contained relatively high amounts of antimony with median values of 13 µg/g, corresponding to 15.6 µg Sb₂O₃/g. The 90th percentile in the same publication was close to 50 µg/g, corresponding to 60 µg Sb₂O₃/g. When taking the CSOIL (parameter set for human exposure modelling) estimate for particulate matter (dust) in indoor air of 52.5 µg/m³ into consideration (Otte et al., 2001), 15.6 µg Sb₂O₃/g dust corresponds to 0.819 ng Sb₂O₃/m³. This is considered a typical value. A reasonable worst case scenario of 60 µg Sb₂O₃/g corresponds to 3.15 ng Sb₂O₃/m³.”*

To conclude on consumer exposure, values that are available for indoor use suggest that the exposure is below the limit values as presented in section 3, also from a precautionary point of view, considering the occupational exposure limit of Germany at 6 µg/m³.

6.2. Environmental exposure estimation

According to the EU RAR,⁷⁵ diantimony trioxide is released to the environment through air effluents and waste water from manufacture, formulation, processing, use and disposal of diantimony trioxide. Further unintentional emission sources are production of non-ferrous metals, coal combustion and road traffic. Therefore, environmental exposure for diantimony trioxide cannot be associated specifically to the use in EEE.

Diantimony trioxide dissolves in the environment and is present as different antimony species, depending on the environmental conditions. Antimony can be found in all environmental compartments. In the Screening Assessment of the Canadian Ministries of the Environment and of Health,⁷⁶ it is noted that the soluble forms of antimony like ATO (though poorly soluble) generally have a moderate potential to cause harm to aquatic, soil and sediment organisms. It is concluded there that the substance is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or

⁷⁴ Op. cit. EU RAR (2008)

⁷⁵ Op. cit. EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

⁷⁶ Environment Canada, Health Canada (2010): Screening Assessment for the Challenge Antimony trioxide (Antimony oxide) Chemical Abstracts Service Registry Number 1309-64-4; September 2010; https://www.ec.gc.ca/ese-ees/9889ABB5-3396-435B-8428-F270074EA2A7/batch9_1309-64-4_en.pdf, last viewed 19.04.2018

its biological diversity or that constitute or may constitute a danger to the environment on which life depends.

6.2.1. Monitoring data: remote regions, biota

In the EU RAR⁷⁷, different background levels of antimony are defined as antimony occurs naturally: natural background concentration (a situation before any human activity), baseline background concentration (corresponding to very low anthropogenic pressure), ambient concentration (diffuse anthropogenic input in the past or present) and realistic worst-case ambient concentration.

According to the EU RAR, antimony concentration measured in air varies and mostly depends on the emissions by road traffic or metal smelting and manufacturing industries: *“The measured concentrations in European air normally range from background values of about 0.1 ng Sb/m³ in remote areas of Norway, to several tenths of ng Sb/m³ and above in areas with heavy traffic or in regions with metal smelting and manufacturing industries. The concentrations (from several thousand to several tens of thousands of ng Sb/m³) of methylated antimony measured in sewage gas and landfill gas (see section 3.1.2.7.2 above) indicate that these kinds of sources may, at least at a local scale, be important.”*

6.2.2. Monitoring data: waste management

No monitoring data were found that measure ATO released into the environment by WEEE treatment plants. The environmental exposure by WEEE treatment is not further elaborated.

It should be noted that there are legislative measures in place that set e.g. air emission limit values for waste incineration plants (IED Directive 2010/75/EU; see also section 1.3.2).

⁷⁷ EU RAR European Union Risk Assessment Report (2008): Diantimony trioxide, November 2008

7. IMPACT AND RISK EVALUATION

It should be noted that for halogenated flame retardants applied with ATO, the use of the latter allows applying less halogenated flame retardants. From the human health and environmental perspective, the application of ATO should not be assessed alone but together with the halogenated flame retardant. However, as such a combined/cumulative assessment is not in scope of this dossier, these considerations cannot be further explored.

7.1. Impacts on WEEE management as specified by Article 6 (1)a

Article 6 (1)a of the RoHS Directive stipulates that specific account should be taken on whether a substance selected for a review *“could have a negative impact during EEE waste management operations, including on the possibilities for preparing for the reuse of waste EEE or for recycling of materials from waste EEE”*.

As diantimony trioxide is solely used in combination with halogenated flame retardants, diantimony trioxide is used in the plastic waste stream as one sound parameter to sort out plastic containing brominated flame retardant As described in the stakeholder contribution by KU Leuven,⁷⁸ the presence of ATO in plastics is commonly used to sort out the plastic for incineration. Post-shredder sorting techniques separate plastics containing diantimony trioxide-based flame retardant systems with a high efficiency from other non-flame retardant plastic types, because of the high density of antimony trioxide ($\rho = 5,7 \text{ g/cm}^3$). According to the KU Leuven,⁷⁹ also X-ray fluorescent-based optical sorting techniques are used alternatively or in combination with density-based sink-float sorting techniques after size reduction by shredding as state-of-the-art recycling processes in Europe. This fraction is as of today's state of the art not recycled but is sent to incineration with energy recovery. The reasons are that there is no further post-shredder sorting of different plastic materials to obtain a required purity, e.g. to separate the plastic material ABS and HIPS both containing brominated flame retardants.

According to the draft Ecodesign regulation for electronic displays⁸⁰, the plastic containing halogenated flame retardants are sent to incineration not because of sorting problems but because of the restriction of some halogenated compounds e.g. under RoHS: *“Separation of plastics containing permitted halogenated compounds from the non-permitted ones is not cost-effective, resulting in all being incinerated.”*

⁷⁸ Op. cit. KU Leuven-University of Leuven (2018)

⁷⁹ Op. cit. KU Leuven-University of Leuven (2018)

⁸⁰ See the draft document at: [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=pi_com:Ares\(2018\)5173952](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=pi_com:Ares(2018)5173952); for Annexes, see https://ec.europa.eu/energy/sites/ener/files/documents/c-2019-2122_1_en_annexe_acte_autonome_part1_v6.pdf

Recital (18): *“Presence of halogenated flame retardants represents a major issue in the recycling of plastics of electronic displays. Some halogenated compounds have been restricted by Directive 2011/65/EU because of their high toxicity, others are still allowed. Separation of plastics containing permitted halogenated compounds from the non-permitted ones is not cost-effective, resulting in all being incinerated. Alternative solutions would exist for the bulk of the plastic part in an electronic display, such as the enclosure and stand, permitting higher yields of recycled plastics. Use of halogenated flame retardants in these parts should be limited, however legislative instruments other than eco-design may be considered better suited. Detailed plastic marking, particularly in respect to any flame retardant shall be required in any case also in light of a future review of the regulation.”*

In order to provide higher yields of recycled plastics and to contribute to the requirements of a circular economy, the draft ecodesign requirements for electronic displays⁸¹ lay down that the use of halogenated flame retardants is not allowed in the enclosure and stand of electronic displays.

To conclude, ATO used as synergist together with brominated flame retardants does not have a negative impact on the recycling of materials from waste EEE because ATO is used as a sound parameter to sort out plastic containing brominated flame retardants; ATO in this process has to be recognized as supporting the sorting technique based on sink-float that is the commonly applied process. In this sense, ATO supports to separate plastic fractions where the fraction not containing ATO might be recycled.

The plastic fraction containing ATO (and brominated flame retardants) is not recycled but incinerated. The recovery of antimony from the ashes of the incinerated plastics is so far not common practice according to the KU Leuven. Campine (2018) also states that *“the recovery of antimony out of plastics is not yet implemented on a broader scale because the operation is not economically viable yet and rather complex (due to pop’s in FR plastics).”* i2a (2018) explains that *“in a number of countries, bottom ash is used for road and other constructions, unless the concentration of ATO in the ash exceeds a particular limit, in which case it must be treated as a hazardous waste (i.e. landfilled).”*

7.2. Risks for workers

The exposure estimation gained by ECETOC for the process of plastic shredding shows that there are potential risks for human health due to exposure to ATO that need to be managed. These results indicate that protection routines have to be established in waste recycling plants in Europe.

The measurements from occupational settings like in Julander et al. (2014) relativise the high exposure estimation provided by ECETOC TRA: The measured data are way below the estimates and also below the national occupational exposure limit (OEL) which is mostly set at 0.5 mg/m³. However, it has to be pointed out that this OEL was recently decreased to 0,006 mg/m³ in Germany. This divergence in national OEL for antimony and its compounds indicates that the risk for workers associated with the exposure to ATO has not been assessed according to uniform principles in Europe. The deviations in the national OEL by a factor of 100 make it difficult to draw a conclusion here.

Moreover, the following circumstances are difficult to assess: In Europe, it is a precondition that recycling plants are equipped with proper ventilation and that the protection of workers is ensured. While it has been established by Julander et al. (2014) that two of the three Swedish e-waste recycling plants participating in the survey had process ventilation, process ventilation did not cover all areas in one company. The reason for not using process ventilation given by the third company was that operations had been outsourced into a temporary building. Therefore, it is difficult to assess whether workplace measurements are representative for European recycling plants or whether the estimates provided by ECETOC TRA are more appropriate. ECETOC TRA is considered to be a recognised tool to be used in this context. In the case of the phthalates DEHP,

⁸¹ European Commission, 7 February 2019: ANNEXES to the COMMISSION REGULATION (EU) .../... laying down ecodesign requirements for electronic displays pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Commission Regulation (EC) No 1275/2008 and repealing Commission Regulation (EC) 642/2009; <https://data.consilium.europa.eu/doc/document/ST-6246-2019-ADD-1/en/pdf>

DBP and BBP⁸², the estimates for workplace exposure provided by ECETOC TRA have been used to substantially support the decision to restrict the phthalates and add them to the RoHS Annex II. Thus, great importance has been attached to the exposure estimations derived from ECETOC in the context of RoHS assessments as mentioned above. In our opinion, this was due to the fact that the precise conditions prevailing in the respective e-waste recycling facilities and the level of workers' protection were not known.

To conclude, an impact on workers in the formal WEEE recycling by ATO is inconclusive. Against the background of varying national OELs for ATO, there might be different views on the potential risks which workers in WEEE recycling face.

7.3. Risks for consumers and neighbouring residents

The EU risk assessment⁸³ came to the conclusion for inhalation of indoor air that there was no concern for consumers.

Indirect exposure via the environment, in addition to indoor air, exists from ambient air, drinking water and foodstuffs. The assessments in the EU RAR⁸⁴ and the Screening Assessment of the Canadian Ministries of the Environment and of Health⁸⁵ both came to the conclusion that the total exposure level to ATO resulting from environmental media is expected to be low.

KEMI (2015) summarizes the additional assessment of the United States Environment protection Agency (US EPA) as follows: *“Based on a review of the available data regarding antimony concentrations in food and environmental media, and biomonitoring data, EPA sets the conclusion that general population exposure to antimony is expected to be low. Because food and water are the primary sources of general population exposure, and the less toxic (i.e., pentavalent) form of antimony predominates in these media, significant human health risks are not anticipated.”* This is also relevant for ATO, because it is expected to dissolve in contact with environmental compartments and to transform in other antimony forms.

7.4. Risks for the environment

There are no specific data on the release of diantimony trioxide from EEE or EEE waste management into the environment. Therefore, general results regarding ATO entering the environment are considered in the following.

The Screening Assessment of the Canadian Ministries of the Environment and of Health,⁸⁶ which is the most recent evaluation of ATO, concludes that diantimony trioxide is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity, or that constitute or may constitute a danger to the environment on which life depends.

⁸² AUBA Austrian Umweltbundesamt (2014): RoHS ANNEX II Dossier DEHP, Restriction proposal for hazardous substances in electrical and electronic equipment under RoHS, January 2014.

⁸³ Op. cit. EU RAR (2008)

⁸⁴ Op. cit. EU RAR (2008)

⁸⁵ Op. cit. Environment Canada, Health Canada (2010)

⁸⁶ Op. cit. Environment Canada, Health Canada (2010)

Against these findings it is concluded that the impact of ATO that is released during use and waste phase of EEE under the waste management conditions described in this dossier has a low potential to cause harm to the environment.

8. ALTERNATIVES

ATO acts as a synergist for halogenated flame retardants. As the scope of this assessment addresses ATO on its own and in combination with the halogenated flame retardants included in this current review, this section on alternatives will cover the following possibilities for substituting ATO:

- Substituting ATO as a synergist, also referred to as mono-substitution;
- Substituting the halogenated flame retardant together with ATO as synergist ATO – hereafter referred to as co-substitution;
- Alternative technologies.

Various information sources have been used to gather information on alternatives and to compensate for missing information from stakeholders during the consultation. Besides information by manufacturers of alternatives, voluntary industry approaches have been reviewed. Furthermore, other studies have been investigated. Regarding costs, it should be noted that, generally speaking, data are hardly explorable in desktop research, and information on costs are vague.

8.1. Availability of substitutes / alternative technologies

8.1.1. Alternatives to ATO as synergist for flame retardants

There are other substances acting as synergist. These are based on zinc, tin or other metal salts:

Tin compounds, so-called stannates: There are several stannate compounds on the market under the trade name “Flamtard”⁸⁷; they are used as polymer additive providing the smoke suppressing and flame retardant synergist functions for polymer processing at temperatures below 220°C. They are used as a co-additive in phosphate-based flame retardants to optimise char formation.

Concrete examples are:

- Zinc (hydroxy)stannate ($ZnSnO_3 \cdot 3H_2O$ or $ZnSn(OH)_6$, CAS: 12027-96-2) is available under the trade name Flamtard H;⁸⁸ and can be used in polyvinyl chloride and polymer materials containing halogenated and antimony additives. Thus, it is a synergist that can be used in combination with ATO, but also as a drop-in substitute to the application in halogen-free flame retardant polymer materials.
- Zinc Stannate ($ZnSnO_3$, CAS 12036-37-2; Flamtard S):⁸⁹ is described by the manufacturer for use in antimony-free applications in the electronic industry. Examples for host materials are indicated as follows: PVC systems for cable sheathing, epoxy resins for printed wiring boards, polyamides and surface coatings.

⁸⁷ <https://www.williamblythe.com/markets/polymer-additives/> last viewed 20.11.2019)

⁸⁸ <https://www.williamblythe.com/products/e-k/flamtard-h/>, last viewed 20.11.2019.

⁸⁹ <https://www.williamblythe.com/products/e-k/flamtard-s/>, last viewed 20.11.2019.

- **Zinc borate** is available e.g. under the tradename Firebrake and its flame retarding effect is based on the “co-work” of zinc and boron oxides with additional effects (water release).⁹⁰ According to the product descriptions, zinc borate can be used as a partial or complete replacement of ATO e.g. in flexible PVC.⁹¹ Firebrake 415, zinc borate oxide (Zn₄(BO₂)₆O, EC 420-340-7) is registered under REACH. However, the entry in the ECHA Registered Substances Database does not contain any further information and the tonnage data are confidential.⁹² In halogen-free formulations, zinc borate is used as a synergist with ATH.⁹³ The combination with ATH is applicable in polymers such as several elastomers,⁹⁴ epoxy resins⁹⁵ and polyolefins.⁹⁶ A partial or complete substitution of ATO is indicated for elastomers and halogen-free epoxy resins, for example.

According to figures from the European Flame Retardants Association (EFRA) for 2005, borate and stannate make up a market share in the European flame retardant market based on tonnages of 3.2 %, which is comparable to the 3.4 % market share of ATO.⁹⁷ In contrast, the ZVEI⁹⁸ (2018) stated that “*while there might be also alternative synergists for brominated flame retardants, no use of such synergists is known to us. Therefore, possible alternatives to the system brominated flame retardant / antimony trioxide are usually halogen-free flame retardant systems based on phosphorus or nitrogen.*” As this substitution is a co-substitution of halogenated FR and synergists, this will be discussed further under 8.1.2.

It can be concluded that there are alternative synergists available on the market; however, the mono-substitution of ATO where the application of the halogenated FR remains can be considered as being of lower priority compared to the possibilities for substituting ATO.

8.1.2. Alternative flame retardants to the combination of halogenated flame retardants and ATO

Substituting both, halogenated FR and the synergist ATO, seems the most promising alternative to ATO, entailing a double positive effect through the additional elimination of the halogenated substance.

Though the ZVEI (2018) states that “*the substitution of halogenated by halogen-free materials is a very big challenge due to several technical requirements especially for existing parts. In consequence no case of a successful substitution in existing parts is known.*” In contrast to the statement of the ZVEI, KEMI⁹⁹ elaborates that “*ATO [as well as halogenated FR such as TBBP-A] is already included in 10 out of 13 examined companies’ chemical lists of hazardous substances that should be limited or phased out, and there are examples of companies that already have phased out ATO.*”

⁹⁰ <https://www.borax.com/products/firebrake>

⁹¹ Firebrake® ZB to replace antimony oxide at <https://www.borax.com/BoraxCorp/media/Borax-Main/Resources/Brochures/firebrake-zb-antimony-oxide.pdf>

⁹² ECHA Registered Substance Database: Entry for FIREBRAKE 415; <https://echa.europa.eu/registration-dossier/-/registered-dossier/4286>, last viewed 17.07.2019

⁹³ Op. cit. Phosphorus, Inorganic and Nitrogen Flame Retardants Association PINFA (2017)

⁹⁴ <https://www.borax.com/BoraxCorp/media/Borax-Main/Resources/Brochures/firebrake-zb-elastomers.pdf>

⁹⁵ <https://www.borax.com/BoraxCorp/media/Borax-Main/Resources/Brochures/firebrake-zb-epoxy.pdf>

⁹⁶ <https://www.borax.com/BoraxCorp/media/Borax-Main/Resources/Brochures/firebrake-zb-polyolefins.pdf>

⁹⁷ The European Flame Retardants Association EFRA (2007): Flame Retardants, Frequently Asked Questions; EFRA - January 2007 at https://www.flameretardants-online.com/images/itempics/2/9/1/item_18192_pdf_1.pdf

⁹⁸ Op. cit. ZVEI (2018)

⁹⁹ Op. cit. KEMI (2015)

The companies' lists of some computer manufacturers confirm the restriction of ATO for all their materials: There are voluntary restrictions for ATO by Apple¹⁰⁰ and Dell¹⁰¹). Samsung's¹⁰² voluntary restriction applies to ATO in *"Mobile phones and Tablets (including accessories and chargers); MP3 players (including accessories); Digital cameras and Camcorders: Main PWB, case and internal wires; TVs: internal wires (except LCD/LED panel and PDP module); Notebooks (except power cord and adapter), Monitors: internal wires (except panel); Home theatres: internal wires."* It can be concluded that the voluntary phase-out of ATO by these companies means the simultaneous phase-out of halogenated flame retardants. This also shows that alternatives for co-substitution are available.

Furthermore, some ecolabel schemes restrict halogenated flame retardants, e.g. TCO Generation 8, for all-in-one PCs, desktops, notebooks and displays.¹⁰³ However, from this mandate *"exempted are printed wiring board laminates, electronic components and all kinds of cable insulation."* With regard to further ecolabels that also ban halogenated substances as flame retardant and partly also as polymer, e.g. TÜV Green Product Mark Computers or EPEAT Computer & Display (IEEE); however, the formulation coverage varies. When halogenated polymers are also banned, there are exemptions e.g. for cable insulation.

The voluntary approaches mostly do not indicate the flame retardant by which ATO and the halogenated FR are substituted. The ecolabel scheme TCO Generation 8 that requires that *"non-halogenated flame retardants [...] appear on the public TCO Certified Accepted Substance List"* has an exemptional character. The TCO Certified Accepted Substance List¹⁰⁴ lists ten flame retardants (Table 8-1).

¹⁰⁰ Apple Regulated Substances Specification 069-0135-K, September 2018;

https://www.apple.com/environment/pdf/Apple_Regulated_Substances_Specification_Sept2018.pdf

¹⁰¹ Dell Specification, Materials Restricted for Use, Document Number: ENV0424 Revision:A03-00; <https://i.dell.com/sites/doccontent/shared-content/solutions/en/Documents/ENV0424-A02.pdf>

¹⁰² Samsung Electronics, Standards for Control of Substances used in products (SEC Registration No. 0QA-2049), Revision 19, October 13, 2017; <https://www.samsung.com/us/smg/content/dam/samsung/sg/aboutsamsung/2017/environment/pdf/standard-substances-products-en.pdf>

¹⁰³ The Scheme requires that *"parts that weigh more than 25 grams (10 g for headsets and 5 g for smartphones) and are made mainly of plastics must not contain flame retardants or plasticizers with halogenated substances or intentionally added halogens as part of the polymer."*; TCO Generation 8 (as of 2018) for displays, notebooks, tablets, desktops, all-in-one PCs; <https://tcocertified.com/certification-documents/>

¹⁰⁴ TCO Certified Accepted Substance List, last updated: 27 May 2019: <https://tcocertified.com/accepted-substance-list/>

Table 8-1: Halogen-free (thus ATO-free) flame retardants according to the TCO Certified Accepted Substance List (further details on the substances in the following chapter)

Category	Entries from the TCO Certified Accepted Substance List
Metal hydroxides	<ul style="list-style-type: none"> Aluminium hydroxide Magnesium Hydroxide
Organic phosphorus based FR	<ul style="list-style-type: none"> Aluminium Diethylphosphinate Bisphenol A diphosphate Substituted Amine Phosphate mixture Triphenyl phosphate Tetrakis(2,6-dimethylphenyl)-m-phenylene biphosphate Phenoxyphosphazene
Inorganic phosphorus based FR	<ul style="list-style-type: none"> Red Phosphorus
Siloxanes & silicones	<ul style="list-style-type: none"> Siloxanes and silicones, di-Methyl, di-Phenyl, polymers with Phenylsilsequioxanes (CAS 68648-59-9)

Source: TCO Certified Accepted Substance List, last updated: 27 May 2019: <https://tcocertified.com/accepted-substance-list/>

From the table above a trend can be seen towards halogen-free organo-phosphorus compounds (among others) as indirect alternatives to ATO which is not applied as synergist to these FR anymore. Especially for the TBBP-A/ATO combination, more concrete alternatives are discussed in the TBBP-A dossier.

The outlined findings allow the conclusion to be drawn that halogen- and ATO-free are available and are already being applied. Nevertheless, the results indicate that substitution of parts of EEE with high energy density might still be challenging, as power cords, power adapters and display panels are exempted from some of the lists cited above.

8.1.3. Alternative technologies

An alternative technology would mean eliminating the use of both flame retardant and the synergist by e.g. the use of inherent flame retardant materials. Examples are:

Metal enclosures/housings for IT products, e.g. aluminium: This shift is done by some manufacturers especially where the application of metal enclosures has additional benefits such as higher durability in notebooks. There are notebooks with metal enclosures by e.g. Acer¹⁰⁵, Apple¹⁰⁶, Asus,¹⁰⁷ Dell,¹⁰⁸ and HP¹⁰⁹ with comparable prices compared to the latest developed laptops with plastic enclosures.

¹⁰⁵ Acer Spin 5 Notebook; <https://www.acer.com/ac/de/DE/content/model/NX.H62EG.001>

¹⁰⁶ Apple MacBook Air Notebook; <https://www.apple.com/de/shop/buy-mac/macbook-air>
 Apple Ipad (pro); <https://www.apple.com/de/shop/buy-ipad/ipad-pro>

¹⁰⁷ Asus ZenBook 14 UX431FA Notebook, <https://www.asus.com/de/Laptops/ASUS-ZenBook-14-UX431FA/>

¹⁰⁸ Dell Inspiron 13 7000 Laptop; <https://www.dell.com/de-de/shop/laptops-2-in-1-pcs/inspiron-13-7000-laptop/spd/inspiron-13-7380-laptop>

- **Inherently non-flammable polymers:**

- PINFA in its brochure from 2017¹¹⁰ describes recent developments in the field of flame retarded thermoplastic elastomers, however, only for cable applications:
 - Use of metal hydroxides in wire and cable applications, where the metal hydroxides ATH and MDH are used in polyethyl Co-vinyl Acetate (EVA)-based cable compounds that contain modified nanoclays (organoclays) so that the content of the traditional flame retardant in these compounds can be reduced.
 - Thermoplastic elastomers (TPE) consist of a thermoplastic urethane as monomer and copolyesters and polyether block amide. There are different TPE types with different desired properties. *“Metal phosphinates can effectively balance mechanical properties and flame retardancy in TPEs. Polyphosphonates have also been found to perform well in TPE-E systems.”*
 - Thermoplastic urethanes consist of hydroxyl terminated polyesters or polyethers and diphenylmethane diisocyanate. By adding 12-15 % metal phosphinate in fine grades with nitrogen synergists or by adding formulations containing melamine cyanurate, the flame retardant classification UL 94 V-0 is achieved. Polyphosphonates are also used in specific applications where e.g. transparency is desired, and also work synergistically with melamine cyanurate and metal phosphinate for improved flame retardancy and mechanical properties.

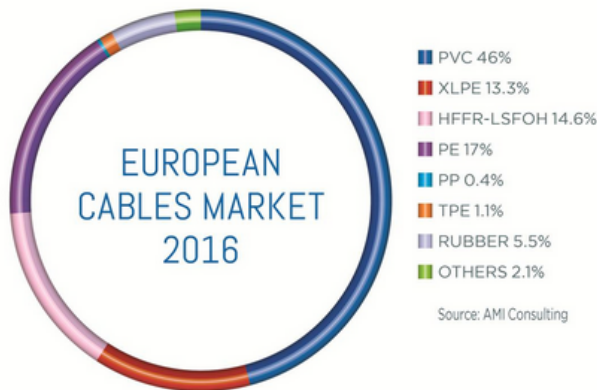
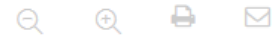
The actual application of these polymers in cables is difficult to determine. The webpage of PVC4Cables, a platform of the European Council of Vinyl Manufacturers (ECVM), specifies the share of other polymer material according to a figure presented in the following. It has to be noted, however, that this covers all kinds of cables and not only low voltage cables as used in EEE. According to these figures, at least TPE is applied, though to the low percentage of 1.1 %.

¹⁰⁹ HP SPECTRE NOTEBOOK; <https://store.hp.com/GermanyStore/Merch/Offer.aspx?p=c-hp-spectre-notebook>

¹¹⁰ Pinfa (Phosphorus, Inorganic and Nitrogen Flame Retardants Association) (2017): Flame retardants in electric and electronic applications, non-halogenated phosphorus, inorganic and nitrogen (PIN) flame retardants; October 2017, 3rd edition; https://www.pinfa.eu/wp-content/uploads/2018/05/PINFA_EE_brochure_Edition_2017-11.pdf, last viewed 24.07.2018.

Figure 8-1: Share of polymers used in cable sheeting and insulation on the European cable market 2016 according to ECVM

Market



PVC cables have a well established cost/ performance track record. In 2016, PVC accounted for 46% of the European cables market. PVC maintains its historical dominance in the low-voltage cables sector with a market share of around 70%.

Source: <https://www.pvc4cables.org/en/pvc-cables/market>, last viewed 17.07.2019

For plastics enclosures in EEE, the Swedish Chemicals Agency KEMI (2015) concludes that *“replacement by polymer alloys is possible, but this might lead to higher costs and still requires up to 0.5 % halogen addition (PTFE).”* UBA (2008) mentions that PC and PPE could be used as alternatives on the material level for ABS so as to eliminate the use of halogenated FR/ATO¹¹¹. Another proposition is the substitution of currently applied housing polymers by liquid crystal polymers (LCP). As in general, also for this alternative pros (*“several very good properties”*, ZVEI (2018)) and cons (*“specific drawbacks”* ZVEI (2018)) exist without further specification. For now, it is not yet clear to which extent housing materials used for other equipment could be suitable here.¹¹²

¹¹¹ UBA (2008) Bromierte Flammschutzmittel –Schutzengel mit schlechten Eigenschaften. (in German) <https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3521.pdf>

¹¹² Op. cit. Morose 2006

To conclude, the two most promising steps forward concerning the substitution of ATO are the co-substitution of the halogenated FR with which ATO is applied as synergist, and the option of alternative technologies which basically means a substitution of the polymeric host material. Literature provides these alternatives, but the actual application in products recently placed on the market cannot be confirmed properly, the reason being that consultants would require concrete confirmation by stakeholders which is still missing.

Questions for stakeholders participating in the stakeholder consultation:

- 1.) Can you confirm the conclusion that the most promising substitution routes for ATO are (a) substituting the halogenated flame retardant together with ATO as synergist ATO, and (b) alternative technologies?
- 2.) The outlined findings indicate that substitution of some components and parts of EEE might still be challenging. If this is the case, please provide evidence for which parts substitution is seen to be difficult. Please provide details on reasons.
- 3.) Which technical criteria are relevant for substitution?
- 4.) To what extent does line density affect substitution, especially regarding power cords, power adapters and display panels?
- 5.) Please provide information on actually applied alternatives, especially on the application of inherent flame retardant materials.

8.2. Hazardous properties of substitutes

In the following, the hazardous properties of the alternative synergists are depicted. Based on the information as provided in the ECHA Information on Chemicals database, the synergists zinc stannate and zinc (hydroxy)stannate are not classified as hazardous. Thus, the stannate compounds can be considered as less harmful alternative to ATO.

On the contrary, zinc borate was assessed in the United States during the Green Screen Assessment of DecaBDE and alternatives and was assessed as being of high concern for genotoxicity (US EPA 2014).¹¹³

¹¹³ United States Environmental Protection Agency US EPA (2014): An alternatives assessment for the flame retardant Decabromodiphenyl ether (DecaBDE), Final Report, January 2014; https://www.epa.gov/sites/production/files/2014-05/documents/decabde_final.pdf, last viewed 24.07.2019

Table 8-2: Hazardous properties of substitutes for diantimony trioxide as a synergist

Substance (CAS)	Harmonized classification	Restrictions under REACH	Human Health and Environmental Concerns	Additional comments
Zinc stannate (12036-37-2)	None	None	According to the majority of notifications provided by companies to ECHA in CLP notifications, no hazards have been classified.	According to KEMI (2015), Zinc stannate is not classified as hazardous but the substance has been self-classified as H315 Skin Irrit. 2, Causes skin irritation, H319 Eye Irrit. 2, H335 STOT SE 3a.
Zinc (hydroxy) stannate (12027-96-2)	None	None	According to the majority of notifications provided by companies to ECHA in CLP notifications, no hazards have been classified.	
Zinc borate (1332-07-6) e.g. "Firebrake": Zinc borate oxide (Zn ₄ (BO ₂) ₆ O)	None	None	According to the classification provided by companies to ECHA in REACH registrations, this substance is very toxic to aquatic life, is toxic to aquatic life with long-lasting effects, is suspected of damaging fertility or the unborn child and causes serious eye irritation. No data available for the commercial "Firebrake".	Under the IUPAC name zinc borate, there are several substances in the ECHA Information on Chemicals database. A green Screen Assessment by US EPA in 2014 points out a high concern for genotoxicity.

Source: ECHA Information on Chemicals database, KEMI (2015), US EPA (2014)

The hazardous properties of the non-halogenated flame retardants as allowed by the TCO ecolabel scheme are compiled in the following table.

Table 8-3: Hazardous properties of alternatives to halogenated flame retardants according to TCO generation 8

Substance	CAS	Harmonized classification	Restrictions under REACH	Human Health and Environmental Concerns
Aluminium Diethyl-phosphinate	225789-38-8	No harmonized classification	None	The European FP7 research project Enfiro (https://www.enfiro.eu) reached the following conclusion for this substance: low acute (eco-)toxicity and no bioaccumulation potential; limited degradation (persistence); moderate chronic aquatic toxicity
Aluminium hydroxide	21645-51-2	No harmonized classification	None	According to KEMI (2018), no risk to human health, data gaps concerning environmental hazards
Red Phosphorus	7724-14-0	No harmonized classification	None	According to the classification provided by companies to ECHA in REACH registrations, this substance is fatal if swallowed, is fatal if inhaled, causes severe skin burns and eye damage, is very toxic to aquatic life and catches fire spontaneously if exposed to air (ECHA Brief Profile)
Bisphenol A diphosphate	181028-79-5; 5945-33-5	No harmonized classification	None	In 2012, ECHA RAC concluded to remove the harmonized classification of Aquatic Chronic 4 (May cause long-term adverse effects in the aquatic environment), ¹¹⁴ resulting in no classification for Bisphenol A diphosphate
Substituted Amine Phosphate mixture	66034-17-1	No harmonized classification	None	No further information found.
Triphenyl phosphate	115-86-6	No harmonized classification	Added to CoRAP in 2013; Regulatory management option analysis (RMOA) submitted by	According to CoRAP justification, ¹¹⁵ potential endocrine disruptor; RMOA due to concerns of endocrine disruption and skin sensitizer ¹¹⁶

¹¹⁴ ECHA Risk Assessment Committee ECHA RAC (2012): Opinion proposing harmonised classification and labelling at EU level of (1-methylethylidene)di-4,1-phenylene tetraphenyl diphosphate; Bisphenol A Diphosphate; Bisphenol A Polyphosphate

<https://echa.europa.eu/documents/10162/f414039f-a858-54ce-66fe-4919774e597b>, last viewed 24.07.2019

¹¹⁵ UK CA (2013): Justification for the selection of a candidate CoRAP substance; <https://echa.europa.eu/documents/10162/47fa7ee3-8323-4532-bb52-f1d8fe3b5ea4>, last viewed 25.09.2018

¹¹⁶ <https://echa.europa.eu/de/rmoa/-/dislist/details/0b0236e181b00e8a>

Table 8-3: Hazardous properties of alternatives to halogenated flame retardants according to TCO generation 8

			France in 2017	
Tetrakis(2,6-dimethylphenyl)-m-phenylene biphosphate	139189-30-3	Skin Sens. 1 - H317	None	According to the harmonised classification, this substance may cause an allergic skin reaction. Additionally, the classification provided by companies to ECHA in CLP notifications identifies that this substance may cause long-lasting harmful effects to aquatic life (ECHA Brief Profile)
Siloxanes and silicones, di-Me, di-Ph, polymers with Ph silsesquioxanes	68648-59-9	No harmonized classification	None	No further information found
Magnesium Hydroxide	1309-42-8	No harmonized classification	None	According to the classification provided by companies to ECHA in CLP notifications, this substance causes serious eye irritation, causes skin irritation and may cause respiratory irritation (ECHA Brief Profile)
Phenoxyphosphazene	890525-36-7; 2791-22-2; 2791-23-3	No harmonized classification	None	No further information found

Source: KEMI (2018); European Chemicals Agency ECHA, <https://echa.europa.eu>

It should be highlighted that the human and environmental health hazards of the organophosphate esters differ depending on the side group of the phosphate.¹¹⁷ Most non-chlorinated alkylated organophosphates are currently registered without restriction under REACH.

However, some arylated organophosphates are suspected as being potential endocrine disruptors (e.g. Triphenylphosphate). Thus, current substance evaluations and listings of substances on the CoRAP list should carefully be considered when choosing substitutes.

Polymers do not have to be registered under REACH; therefore no (eco-) toxicological data have to be submitted to ECHA before bringing the polymers onto the market. As a consequence, an assessment of hazardous properties of polymers mentioned in section 8.1.3 is not possible. Still, phasing out halogenated flame retardants including ATO as a synergist by using inherent inflammable polymers could be a step forward as far as a conclusion on the polymers' suitability is possible.

¹¹⁷ Chlorinated organophosphates also belong to halogenates substances. Thus, they are not further considered.

8.3. Data basis for alternatives and uncertainties

It is understood that alternatives exist and are applied in some cases. Especially the application of halogen-free enclosures – thus also ATO free – is assured because phosphorous-based flame retardants in EEE enclosures (e.g. LCD TVs) are reported to be found in the waste stream.¹¹⁸ So-called front running companies or ecolabel schemes also ban halogenated substances commonly encountered in plastic parts greater than 25 grams. Still, it cannot fully be concluded whether exemptions of ecolabel schemes or companies are made due to difficulties in substitution or price considerations. As very few companies restrict halogenated substances for all materials like e.g. Apple or Dell, rather the price considerations might be the reason.

In their contributions, stakeholder specify the following applications of ATO in the field of the electrical installations for which a substitution is not possible:

- Electrical and electronic parts with thin walls, e.g. electrical and electronic connectors; ZVEI (2018)
- Electrical and electronic parts with short distance between conductors, e.g. electrical or electronic connector with high density of pins; ZVEI (2018)
- Parts with mechanical connecting function due to the lower elongation at break, e.g. parts for installation in profile rail; ZVEI (2018)
- the hermetic sealing function needed on semi-conductors where no alternatives have been proven to be as technically performant as the ATO+BFR combination; i2a (2018)¹¹⁹ ”.

As earlier pointed out, uncertainties exist concerning the hazardous properties of polymers that, if they are inherently inflammable, this could entail a turning away from the need for BFR/ATO. Secondly, while comprehensive search provided a list of substitutes, the actual application of these substitutes in products cannot be confirmed properly. Finally, especially with regard to so-called not-substitutional applications of ATO, stakeholder contributions are difficult to confirm without concrete knowledge on manufacturing processes, the way in which ATO is applied and the quantities used in this specific application.

8.4. Conclusion on alternatives

To conclude on possible alternatives for ATO, the analysis of the various information sources indicates two most promising steps forward:

- the co-substitution of the halogenated FR with which ATO is applied as synergist, and
- the option of alternative technologies which means basically a substitution of the polymeric host material.

The actual application in products placed on the market cannot be comprehensively recorded as the consultants miss concrete confirmations by stakeholders. There are, however, evidences that substitutes are applied:

¹¹⁸ Op. cit. KU Leuven (2018)

¹¹⁹ i2a in a personal communication by Caroline Braibant, 18. July 2018

- The application of substitution is confirmed by waste stream analysis: Halogen-free enclosures – thus also ATO-free – is assured because phosphorous-based flame retardants in EEE enclosures (e.g. LCD TVs) are reported to be found in the waste stream.¹²⁰
- Voluntary approaches phasing out ATO or explicitly halogenated flame retardants, e.g. certain ecolabel schemes or restricted substance lists of companies. Thus, they use other flame retardants in their product.

Regarding co-substitution, the substitution of the flame retardant to which ATO is a synergist, should be carefully decided on to avoid regrettable substitution.

9. DESCRIPTION OF SOCIO-ECONOMIC IMPACTS

9.1. Approach and assumptions

The scope of this assessment requires a review of possible socio-economic impacts related to a scenario in which antimony trioxide were to be added to the list of restricted substances specified in Annex II of RoHS 2. This would restrict the presence of ATO in EEE to be placed on the market in the future.

ATO is commonly used as a synergist together with halogenated flame retardants with the aim of enhancing flame retardant properties. An added value of the use of ATO in these cases is explained to be that lower quantities of the applied flame retardant can be used. In the case of a restriction, a number of substitution routes could be chosen, depending on the component in which ATO is being substituted and the level of required flame retardancy:

- Substitution of ATO with alternative synergists on the substance level;
- Phase-out of ATO at the cost of an increase in the amount of used flame retardant;
- Substitution through replacement of the applied flame retardant (elimination);

In this respect it is noted that some EEE will already be compliant with the new restriction, seeing that some OEMs already specify ATO as a restricted substance in components and materials purchased from the supply chain (see section 8.1.1) and have already completed the phase-out of ATO. The impacts related to the phase-out of ATO depend on the substitution route as well as on the substitutes chosen. However, it is clear that impacts related to ATO in use and waste management would be expected to decline (depending on the approval of possible temporary exemptions).

9.2. Impact on chemicals industry

Impacts on this industry depend on the route (see section 8.1) chosen:

- In the case of a substance substitution a parallel increase in sales of other synergists would be expected.
- Should manufacturers of EEE decide to omit the use of a synergist, it is understood that larger quantities of BFRs would be necessary to establish the same levels of retardancy, increasing sales of such substances.

¹²⁰ Op. cit. KU Leuven (2018)

- Elimination of the need for ATO through the replacement of the BFR with other flame retardants shall result in an additional increase in sales of alternative flame retardants and a decrease in BFR sales. It is noted that halogenated flame retardants and non-halogenated flame retardants are not necessarily manufactured by the same producers and that this type of phase-out could lead to a shift of business between various manufacturers. In relation to BFRs it is also noted that there are only a few global locations where bromine is sourced. For example, both in Jordan and Israel, bromine is sourced from the Dead Sea. In both countries, these chemical industries provide a significant source of income and employment, while also having an impact on the surrounding environment. Therefore reduction in the production of BFRs would also decrease such extraction¹²¹.

9.3. Impact on EEE producers

A possible phase-out of ATO and possibly of certain halogenated flame retardants shall generate costs to the EEE industry and its suppliers. Such costs are related not only to the difference in costs between ATO and alternative synergists (or between the combination of ATO and BFRs with the replacement flame retardant), but rather also to costs of redesign, testing and implementation of relevant substitutes. As it is apparent that substitutes exist for ATO as well as for BFRs, it can be assumed that the phase-out would progress quickly in some areas, particularly where experience has been gained with alternatives through voluntary phase-out to have already taken place.

In any case, the general cost differences of such products also mean that OEMs shall view the burden of costs of a substitution differently, and this may differ between OEMs based in the more developed countries and OEMs based in less developed ones. In some areas phase-out may be more difficult. Stakeholders mention several applications of diantimony trioxide in the field of electrical installations, where it is expected that substitution is not possible. It is unclear how extensive the effort of substitution could be in these cases, however during this period, relevant industries shall need to pursue exemptions to allow further use, generating additional administrative costs in terms of requesting and accompanying the exemption evaluation process (possibly on a repeated basis, should substitution require a longer period of time). Additional administrative costs are attributed to the need to document compliance with the restriction and in some cases to test EEE for such compliance. In general administrative costs are expected to be lower than the costs of substitution. This is based on the understanding that companies shall already have prepared similar compliance documentation in the past for parts where deca-BDE or octa-BDE were traditionally used as flame retardants.¹²²

9.4. Impact on EEE users

In many applications a phase-out of ATO can be expected to be easier on the background of a large range of substitutes already recognized. Consumers are not expected to be affected from such changes in terms of the choice of products available. As a substitution would only be expected in cases where a comparable level of flame retardancy is achieved (compliance with relevant standards) an impact is also not expected in relation to the services/properties provided to consumers from various EEE. In contrast, costs of substitution can be expected to be transferred by the EEE industry to consumers and to increase the costs of relevant EEE. As cables and PWBs

¹²¹ See Samuel Neaman (2007) Reclaiming the Dead Sea Alternatives for Action, available under: http://negev.ilbiz.co.il/upload_pics/English%20version%20300807%20_2_.pdf

¹²² Op cit. Depa (2010)

are used in most EEE, such impacts cannot be expected to be focused in certain categories but to affect most EEE.

9.5. Impact on waste management

The assessment of the impact on the waste management if ATO is restricted is seen ambiguously:

- On the one hand, ATO due to its high specific density allows separating the plastic fractions obtained after shredding and sort out brominated flame retardant plastic in the density based sink-float sorting techniques. In this regard, ATO is considered to facilitate the recycling of WEEE by sorting out hazardous waste or waste that so far cannot be directed to recycling (see section 7.1). A restriction of ATO would also hamper this separation technique as the restriction of ATO does not necessarily lead into a non-use of brominated flame retardants; thus this waste fraction is understood being further existent and thus needs to be sorted out.
- On the other hand, the plastics sorted out based on the presence of ATO for the most part are incinerated or declared as hazardous waste and landfilled at appropriate sites, constituting a loss of antimony which is considered a critical raw material. A phase-out of ATO shall prevent such losses and in that sense have a positive impact in terms of resource efficiency and a shift towards a more circular economy, although this impact does not relate to the criteria under RoHS Article 6(1).

9.6. Impact on administration

Administrative costs for regulators can be expected on the EU as well as the national level. The EU can expect to incur one-time costs related to the amendment of Annex II with the new restriction of ATO. Additional costs may be relevant in the longer term, depending on whether exemptions would be requested and how long such exemptions would remain valid (frequency of revaluations). As for national regulators, costs related to the transition of the amendment into national legislation are also expected in the short term, while additional costs would be associated with the transposition of possible exemptions. Costs related to market surveillance can also be expected to occur on annual basis to ensure compliance with the new regulations. The scope of such costs differs from country to country depending on the (possibly changing) level of activity of the MS in market surveillance.

9.7. Total socio-economic impact

Though various costs are associated with the phase-out of ATO, positive impacts in the waste phase, fulfilling the Article 6(1) criteria are also apparent concerning improved resource efficiency. It should also be noted that though a positive environmental impact could be expected in this respect, it needs to be evaluated whether the shift to various substitutes would not create a negative impact that would to some degree cancel such positive impacts. For example, in cases where the phase-out of ATO shall result in higher amounts of BFRs being used, a negative impact on the environment is to be expected. At present quantification of such aspects is not feasible due to lack of data, however such an analysis would assist in determining whether the possible benefits are proportional to costs.

Current substitute availability also suggests that in many applications, a phase-out is technically feasible, even if it is difficult to estimate the resource (time, financing) required for this change.

Questions for stakeholders participating in the stakeholder consultation:

In order to understand the socio-economic impacts of a potential restriction of ATO in the various fields of applications as described in section 2 more in depth, stakeholders are requested to provide information on the costs and benefits that can be associated with such a restriction of this substance in electrical and electronic substances under RoHS. Within this context, please make available quantitative data wherever possible. However, also qualitative information is considered to be helpful for the assessment of the socio-economic impacts. Concerning the impacts, information should be distinguished and specified according to the following scheme as far as possible:

- *impact on chemicals industry;*
- *impact on EEE producers;*
- *impact on EEE users;*
- *impact on waste management;*
- *impact on administration.*

10. RATIONALE FOR INCLUSION OF THE SUBSTANCE IN ANNEX II OF ROHS

Diantimony trioxide is used as a synergist for halogenated flame retardants, which means that smaller quantities of halogenated flame retardants can be applied. The most relevant applications for ATO identified are plastics (e.g. for EEE enclosures), cables and Printed Wiring Boards and their resins. Substantial information was missing with regard to the question which halogenated flame retardant requires which concentration of ATO. Moreover, there was a lack of specific information on the current quantities of ATO placed on the European market in the above-mentioned applications.

As for the presence of ATO in the waste stream, it has been recognised that ATO is used as a sound parameter in post-shredder sorting techniques to sort out plastic that contains brominated flame retardants due to its high density. It is concluded that ATO therefore rather facilitates the waste management of flame retardants as it enables the use of the sink-float separation technique.

With regard to risks for human health, it is concluded that workers in recycling plants are exposed to ATO especially in dismantling and shredding processes. The potential exposure as estimated by ECETOC TRA indicates a risk exceeding the occupational exposure limits. The results obtained by ECETOC indicate that risk management measures such as proper ventilation have to be installed. Nonetheless, workplace measurements are below the national occupational exposure limits. Thus, available data is contradictory with respect to risks through exposure. In light of the precautionary principle, there is some reason for appropriate measures to take due to the fact that ATO is a recognised carcinogen. Therefore, monitoring of recycling plants to measure the exposure to ATOs should be established.

Although alternatives as synergist to ATO are available, the application of this mono-substitution in products on the market does not seem to be applied. Instead, the application of alternatives to the combination ATO and halogenated flame retardants (co-substitution) is confirmed by waste stream analysis. Voluntary approaches by industry or ecolabel schemes show that substitution rather targets halogenated flame retardants (and thereby ATO as well).

To conclude, if ATO on its own is restricted, there is a risk of regrettable substitution since – as a consequence of this restriction – an increased amount of halogenated flame retardants is expected to be used, bringing along their predominant negative impacts on health and the environment. In order to avoid this, the consultant proposes not to exclusively restrict ATO, but instead to carry out a joint assessment of the system of halogenated flame retardants and the ATO synergist with high priority. This group approach is supported by the RoHS methodology,¹²³ which states that *“a group of substances subject to assessment for potential restriction in EEE should be composed of substances sharing one or a combination of the following similarities: [...] similar or same purpose/use/function in specific applications.”*

¹²³ The methodology is available at <https://rohs.exemptions.oeko.info/index.php?id=341>

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12. Appendix I: Contributions to 1st stakeholder consultation hold from 20 April 2018 to 15 June 2018

The following non-confidential contributions were submitted during the 1st stakeholder consultation (see also: <http://rohs.exemptions.oeko.info/index.php?id=290>):

- > Contribution of the **Swedish Chemicals Agency (KEMI)** submitted on 11.06.2018:
 - >> Assessment of the risk reduction potential of hazardous substances in electrical and electronic equipment on the EU market: [PDF](#)
- > Contribution of the **European Domestic Glass (EDG) and European Special Glass Association (ESGA)** submitted on 13.06.2018, [PDF](#)
- > Contribution of the **Zentralverband Elektrotechnik- und Elektronikindustrie e. V. (ZVEI)** submitted on 14.06.2018: [PDF](#)
- > Contribution of **MedTech Europe** submitted on 15.06.2018: [PDF](#)
- > Contribution of **KU LEUVEN** submitted on 15.06.2018: [PDF](#)
- > Contribution of **SPECTARIS** submitted on 15.06.2018: [PDF](#)
- > Contribution of the **International Antimony Association (i2a)** submitted on 15.06.2018: [PDF](#)
- > Contribution of the **Test and Measurement Coalition (TMC)** submitted on 15.06.2018: [PDF](#)
- > Contribution of the **Association of Equipment Manufacturers (AEM)** submitted on 15.06.2018: [PDF](#)
- > Contribution of **Europacable** submitted on 15.06.2018:
 - >> Part 1: [PDF](#)
 - >> Part 2: [PDF](#)
- > Contribution of the **European Semiconductor Industry Association (ESIA)** submitted on 15.06.2018: [PDF](#)
- > Contribution of the **Japanese electric and electronic (E&E) industrial associations** submitted on 14.06.2018: [PDF](#)
- > Contribution of **Campine** submitted on 15.06.2018:
 - >> Contribution: [PDF](#)
 - >> Annex 1: [PDF](#)
 - >> Annex 2: [PDF](#)
- > Contribution of the **AeroSpace and Defence Industries Association of Europe (ASD)** submitted on 14.06.2018: [PDF](#)

Applications mentioned by stakeholders that are not in scope of this assessment; the following uses are understood to be intermediate uses of diantimony trioxide:

- **Use as clarifying aid in certain glasses:** Contributions of European Domestic Glass (EDG) and the European Special Glass Association (ESGA)¹²⁴, of SPECTARIS¹²⁵ and of the International Antimony Association (i2a)¹²⁶ explain this to be an intermediate use in the synthesis of certain glasses with the purpose of providing specific characteristics to the glass. Accordingly, it is used to provide a specific glass with enhanced transparency by oxidizing the Iron (Fe) ions and thus prevents the color of Fe²⁺ ions. This increases the solar and light transmission. Besides the effect on optical transmission, the addition of Sb₂O₃ in the glass ingredients has an additional effect on the molten glasses in terms of improving turbidity and removing bubbles. It is also used to produce special glass inhibiting the reduction of solarisation effects. Sb ions are present, bound in the glass matrix.
- **Use as opacifying agent in functional ceramics:** According to the i2a¹²⁷ as well as the Zentralverband Elektrotechnik- und Elektronikindustrie e. V. (ZVEI)¹²⁸, diantimony trioxide is added to ceramic minerals at high temperature (800-1000°C). In the final product the antimony ions will be embedded in the ceramic matrix with ionic bonds/semi-covalent bonds to other atoms like oxygen, silicon etc., resulting in some kind of oligomeric or polymeric mixed antimony and silicon oxides.
- **Use as catalyst in the production of PET:** According to the i2a,¹²⁹ ATO is converted during the catalysis. Definitions of a catalyst usually assume that it makes a chemical reaction happen more quickly without itself being changed,¹³⁰ and the EU RAR (2008) states that the “*final concentration of diantimony trioxide in PET is typically around 180 to 220 ppm, but can be up to 550 ppm*”. However, i2a – in other press releases – refer to e.g. the study of Duh (2002)¹³¹ that explains that “*in the commercial process, it is first dissolved in ethylene glycol (EG) at about 150°C under a nitrogen blanket to form antimony glycolate before being added to the*

¹²⁴ European Domestic Glass (EDG) and European Special Glass Association (ESGA) (2018): Contribution submitted on 13.06.2018 during the stakeholder consultation conducted from 20 April 2018 to 15 June 2018 by Oeko-Institut in the course of the study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15);

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¹²⁹ Op. cit. International Antimony Association (i2a) (2018)

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polycondensation reactor. In small-scale lab polymerization experiments, dry Sb_2O_3 can be directly added to the reactor at the beginning of the polycondensation stage. The Sb_2O_3 added is readily dissolved because there is still ample free EG in the reaction mixture.” In the final PET, there remains residual Sb; according to i2a,¹³² “measurable levels of Sb would be typically present in very small (ppb or at worst in ppm²) concentrations”.

¹³² Op. cit. International Antimony Association (i2a) (2018)