EU COM Study to support the review of the list of restricted substances and to assess a new exemption request under RoHS 2 (Pack 15)

1st Stakeholder Consultation
Questionnaire for diantimony trioxide (CAS 1309-64-4; EC 215-175-0)

Responses submitted by i2a
15 June 2018

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i2a introductory statement

The International Antimony Association (i2a) welcomes the opportunity to participate in the Stakeholder Consultation and looks forward to address any gaps or unclear matters which may prevent the EU Commission and its collaborators to conduct the relevant assessment and reach the applicable conclusion on the need or not to restrict the use of antimony trioxide (ATO) in EEE. **i2a strongly believes that there is no need to restrict the use of ATO**, for a number of reasons, outlined below.

Antimony is a critical raw material as published by the European Commission. Critical Raw Materials are those raw materials which:

(a) have a high economic importance for key sectors of the European economy,
(b) have a high-supply risk, and
(c) do not have viable substitutes due to their unique and reliable properties for existing and future applications.

As such, it is recognized that antimony **has unique properties** that can be used to manufacture high performing products and contribute to the competitiveness of the European industry.

It is important to note that any restriction on the use of ATO in flame retardant applications, which is the chief use of ATO and Sb substances in terms of volume, may negatively affect other societally indispensable uses of ATO. **The volumes of ATO needed in flame retardancy solutions renders many other key applications and recycling solutions economically feasible.** Any limitation in the use of ATO as a flame-retardant synergist will trigger an automatic cascade of changes to the larger ATO and Sb substances market. If the use of ATO as flame retardant synergist in EEE somehow decreases or stops due to a RoHS restriction, the viability of important applications in other markets (e.g. specialty glass, medicine, nuclear industry and technical alloys) would immediately be challenged too. If the use and hence production of ATO (or Sb substances more largely) decreases, the continued uses will be possible at prohibitive costs only, and there will be a considerable shift to increased disposal of valuable resources containing Sb and other substances because there would be no viable markets for these anymore (it would be cheaper to dispose of them than to refine and purify them to meet the customers' use specifications). This would go against Europe's Circular Economy goals.

When assessing the specific use of ATO in flame retardant applications, it is of **primordial importance to consider the societal risk trade-off between the loss of lives and property caused by fire, and the supposed adverse impact of the ATO on human health and the environment**. Today, there is by far more evidence demonstrating the added-value of ATO than evidence demonstrating its clear implication in chronic and irreversible adverse effects on human health or the environment. Modern workplace exposure levels and environmental emission levels for Sb applicable to EU production and using sites have shown to be efficient in managing the intrinsic hazard of ATO, ensuring a risk-free/safe use of ATO. (Recent) Exposure to or release of Sb has not irrefutably been associated to human morbidity or mortality in any study.

Recent hazard and exposure evidence is actually being scrutinized under the REACH regulation Substance Evaluation process. ATO and four other Sb substances are being evaluated to determine if any of their uses poses any risk and recommend avenues to address such risks if they are identified. **The REACH Substance Evaluation process intends to clarify a number of concerns and scientific interpretations which will per se be relevant for a possible RoHS evaluation.** The discordancy between the timing of the RoHS shortlisting and REACH Evaluation of ATO (draft decision expected in 2019) does however not permit this synergy and subsequent regulatory efficiency.

ATO is also included in the inventory of plastic additives which is being compiled by the European Chemicals Agency in order to discriminate between higher priority and lower priority additives used in plastics and increase the regulatory efficiency of any risk management measure-related decision. **The RoHS evaluation is likely to gain considerable insights on the relevance, urgency and proportionality of a potential RoHS restriction of ATO if it considers the output of the ECHA Sectorial Approach work**, due to deliver in 2019.

Progressing with a RoHS Evaluation without taking account of the outcomes of the on-going processes described above can only lead to regulatory inefficiency. Indeed, developing an opinion on the basis of an incomplete and possibly misleading picture will render such opinion weak and highly challengeable. Instead, **we recommend that the need to evaluate ATO under RoHS is reconsidered once the informative REACH processes have delivered the most relevant and reliable content**.

The Circular Economy concept and recent improvements in waste export or recycling targets is stimulating and accelerating the progress of ideas, solutions and projects aimed to improve the management and reuse of wastes containing very small and generally not economically relevant levels of chemicals. ATO or flame-retardant containing plastics are no exception. Over the last couple of years, various possibilities to sort and reuse flame retardant containing plastics have been made more concrete, and solutions to make these economically viable have been more seriously developed. **This move towards circularity and sustainability could be stalled by a RoHS restriction, which could hamper the expected returns on investments in such solutions.** This would not only allow continuation of the incineration and landfilling of valuable resource materials, but actually promote such undesired practices.

We request that the European Commission does not proceed to any final proposal or decision-making before all concerns have been clarified under the processes mentioned above. These will in particular be very instrumental to gather a.o. workplace exposure data, also from waste managers and recyclers, to be considered in the RoHS assessment.

Beyond the regulatory efficiency and timeliness of the RoHS evaluation of ATO, there are also a number of questions regarding the scope and purpose of the ATO ‘entry’ in the shortlist of substances undergoing the RoHS evaluation:

- First, the methodology to identify possible candidates for restriction under RoHS has not been finalized, and it is unclear on which objective basis ATO has been included in the shortlist.
- Second, ATO was originally listed for the specific purpose of flame retardancy, but the questionnaire requests information about uses beyond this use. This adds confusion to the scope and purpose of the shortlisting of ATO.
- Third, ATO is used as flame retardant synergist with halogens, and restricting ATO would decrease the performance and resource-efficiency of these halogens, which would be required in higher quantities, without being able to reach the highest fire safety standards (UL94V0). The questionnaire does not explicitly foresee to describe this synergistic function, neither is the ‘synergistic function’ or interdependence of ATO with other chemicals addressed from the scope and purpose of the shortlisting exercise.

- Fourth, many flame-retardant solutions are likely to possess one or the other intrinsic property which may cause a risk under uncontrolled use conditions in EEE; this cannot be assumed to be unique to ATO. For the RoHS assessment exercise to deliver a truly sound and robust opinion, all flame retardants used in EEE and which have a given toxicity profile should be subject to a comparable level of scrutiny, rather than arbitrarily focusing only on one of them.

Based on the above, we would like to note that the questions have been answered as well as possible, in light of the on-going related processes and unclear justification, scope and purpose for the shortlisting of ATO for potential RoHS restriction.

Questions

1. Applications in which diantimony trioxide is in use

a. Please provide information concerning products and applications in which the substance is in use.

i. In your answer please specify if the applications specified are relevant to EEE products and applications or not.

ii. Please elaborate if substitution of the substance is already underway in some of these applications, for example in relation to the properties for which diantimony trioxide is used (for example synergist for halogenated flame-retardants) and/or in relation to specific applications in which it is used (for example in specific plastic materials, etc.) and where relevant elaborate which chemical or technological alternatives may be relevant for this purpose.

Table 1. Products and applications using ATO and their relevance to EEE

	Product and application using ATO	EEE relevance	Annual amounts in EU[1]
1.	PET (films/fibers, resin) production	Not relevant: ATO is used as a catalyst to polymerize **PET**. During the catalysis, ATO becomes triglycolate and co-polymerizes with the PTA and AMG components and would no longer be present in the form of ATO. Measurable levels of Sb would be typically present in very small (ppb or at worst in ppm[2]) concentrations.	950 t/a
2.	Production of flame retardant plastic, resin and rubber	Relevant: **Flame retardancy** is a fire safety quality criterion for EEE parts directly exposed to electricity, electric contacts, or heat. In such flame-retardant components, ATO functions as a flame-retardant synergist (with a halogen, e.g. Cl or Br) and would be present in levels of 2-8% only (with lowest levels found in PVC).	20000 t/a, with: - 70% in EEE plastics (i.e. max 14000 t/a used in EEE (circuit 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)

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[1] Divided as follows: 9 200 t/a in non-PVC plastics, 8 800 t/a in PVC, and 2 200 t/a in rubber. Source: European Chemicals Bureau. 2008. European Union Risk Assessment Report: Diantimony Trioxide. Luxembourg: Office for Official Publications of the European Communities. Available from: https://echa.europa.eu/documents/10162/13630/trd_rar_sweden_diantimony_trioxide_en.rtf/967b2892-8795-4a33-bb34-9587b8679cf9. Data from 2005 can be used as, except for the increase in price of 2012-2013, the antimony market is quite stable. More information about this 'stability' can be found in reports from the German BGR, e.g.: https://www.bgr.bund.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-18.pdf?__blob=publicationFile&v=3 and more recent presentations in various workshops.

[2] Source: Dupont, D.; Arnout, S.; Jones, P.-T. ; and Binnemans, K. 2016. Antimony Recovery from End-of-Life Products and Industrial Process Residues: A Critical Review. J. Sustain. Metall. (2016) 2:79–103. Available from: https://link.springer.com/content/pdf/10.1007%2Fs40831-016-0043-y.pdf.

	Product and application using ATO	**EEE relevance**	**Annual amounts in EU[1]**
			- 10% in other applications (e.g. insulation tapes in automotive sector)
3.	Production of flame retardant textile	None	1750 t/a
4.	Production of wood adhesives	None	50 t/a
5.	Production of flame retarded flexible sealing materials	Cf. use in polymers above and semi-conductor resins below.	20 t/a
6.	Production of glass, enamels, functional ceramics and semi-conductors	Not relevant: **Functional ceramics** are designed for special applications requiring electric, magnetic or optical properties. In such functional ceramics, ATO functions as an opacifying agent. When ATO is added to the ceramic minerals at high temperature (800-1000°C), it will no longer be present as ATO in the resulting ceramic. Not relevant: In **glass**, ATO is added to the batch to chemically interact with other oxides, enhancing optical transmission, turbidity and bubbles removal. ATO is mixed with all the other raw materials, all of which react chemically to produce the substance "glass", which is a network of non-crystalline structures of elements bonded together with oxygen ions between cations (oxygen bonds or bridges). ATO would no longer be present as such in the final matrix, and glass would hence be out of scope. Not relevant: Antimony-based alloys (with Ga and In) are used in **semiconductors** as a dopant in n-type silicon wafers for diodes, infrared detectors, and Hall-effect devices. But this would Antimony metal, and not ATO, and would hence be out of scope. **Semiconductors** are also covered by flame retardant (epoxy) resins, which act as sealing material, which may contain ATO in conjunction with Bismuth Trioxide or Bismuth Nitrate. This happens in a very small percentage of cases. The weight of a semiconductor device is in the range of 0.1 to 20 mg, and the resin represents in average half of the weight, maximum 10 mg. The concentration of ATO in the initial resin (before curing) may go up to 3 % (i.e. less than 0.3 % of the resin, and less than 0.15 % of the semi-	250 t/a

	Product and application using ATO	EEE relevance	Annual amounts in EU[1]
		conductor). ATO is expected to react during curing of the semi-conductor, and therefore not available as such in the final products. The use of ATO in flame retardant resins is in any case covered above.	
7.	Production of pigments, paints, coatings, ceramics, brake pads and production and formulation of fine chemicals	None	1100 t/a

According to Articles 3(1) and 3(2) of the RoHS Directive, *'electrical and electronic equipment' or 'EEE' means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current*; and *'dependent ' means, with regard to EEE, needing electric currents or electromagnetic fields to fulfil at least one intended function*.

In line with the scope of RoHS and the list of uses in Table 1, only the following uses of ATO would be relevant for this questionnaire:

- Flame retardant plastics used in EEE
- Flame retardant rubber used in EEE
- Flame retardant flexible sealing materials used in EEE

From a further volume point of view, the use of ATO in flame retardant plastics is the main use to be considered under RoHS. The response to the questionnaire will hence focus on the use of ATO in flame retardant plastics used in EEE.

b. Please specify if you are aware, if aside from actual use of the substance, it may be reintroduced in to the material cycle through the use of secondary materials.

i. Please detail in this case what secondary materials may contain diantimony trioxide impurities and at what concentrations as well as in the production of what components/products such materials are used.

Secondary/End-of-life/Waste materials which may contain ATO are flame retardant plastics in which ATO was originally used as flame retardant synergist. There are commonly two broad types of plastics: thermoplastics, which can be re-melted and reused, and thermosets, that due to cross-linking in the creation of the initial object cannot be re-melted for reuse, and thus need other solutions as waste to energy recovery or chemical decomposition.

In the EU, the waste of electrical and electronic equipment (WEEE) Directive (EC, 2012) mandates that plastics containing brominated flame retardants be separated from other collected WEEE. When these are diverted to energy recovery or incineration, ATO will be found in the bottom ash. 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).

Where plastics contain valuable metals such as Cu or precious metals, they will be melted with other sources of such metals and the ATO contained in it will be recovered through the Cu and Pb production cycles, as Sb metal or Sb compounds (depending on the refining and purification steps).

The continuous pressure for resources to become truly circular will inevitably influence the above general pattern, towards an increased potential for and strive to maximize the recyclability and recycling of ATO containing materials, including those used in EEE and ultimately becoming WEEE (and subject to WEEE targets).

Table 2. Possible secondary sources in which ATO may be present and recovered from.

	Nature of the Antimony contained	**Industry reusing/recovering the material**	**Description**
End-of-life/Waste plastics, which can be re-melted for reuse	ATO	Plastics	Following the relevant collection and sorting of the various types of polymers, some may be re-melted for reuse as recycled plastic. If used in conjunction with brominated flame retardants, it is likely that those plastics containing ATO as a synergist will be sorted out before plastic recycling or other treatments. When plastic is recycled, it will require to meet a number of performances to be truly reused in flame retardant applications. If it cannot meet such performance levels, it can be reused in applications where consumer exposure is unlikely, i.e. in traffic management and road furniture, roofing and waterproofing sheets, mats for stables and greenhouses, noise insulation sheets, multilayer hoses, professional footwear, etc. Such uses have been studied by ECHA during the restriction on Pb stabilizers.
		Non-ferrous metals	Non-ferrous metals can use a variety of feedstocks when these contain valuable metals (e.g. precious or rare metals). The plastic can be partially reused as fuel for the smelting phase, and the various metals are then recovered from the metallurgical processes following the first smelting phase. This would yield antimony metal or antimony antimonate, depending on the metallurgical reaction that is used to separate the various metals.
Products from the incineration of end-of-life/waste plastics	Antimony metal	Non-ferrous metals	Non-ferrous metals can use a variety of feedstocks when these contain valuable metals (e.g. precious or rare metals). The flue dust from bag filters or bottom

	Nature of the Antimony contained	Industry reusing/recovering the material	Description
			ashes from the incineration plants can be fed to the first smelting phase before the various metals follow a preferential metallurgical stream, depending on their chemical affinity.

ATO would typically be present in concentrations between 2-8% in this end-of-life stage, equivalent to the amount it was originally added to the plastic (cf. response to question c. below for more details) for pure streams of material. However, it is likely that the amount will be much lower in mixed streams.

The recovery of plastics containing certain additives, such as ATO and other flame retardants, is not yet massively implemented because levels contained are very low (on a mass basis), and the operation was not economically viable up to now. Indeed, at the end of life stage, as the level of heterogeneity/complexity of the plastic product increases (different polymer/material types and additives), the ability to effectively sort and recycle them under affordable conditions decreases.

The International Antimony Association, via the Critical Raw Materials Alliance, is requesting that the EU incentivizes and develops cost-effective, resource and energy efficient technologies for the recycling of antimony, to make it technically and economically feasible, and reduce Europe's dependence on imports of CRMs. This topic will furthermore be addressed at the i2a 2018 Antimony Day on Flame Retardants (Brussels, 13-14 November 2018: www.antimony.com/event).

ii. If possible please provide detail as to the changing trends of diantimony trioxide concentrations in such secondary materials as well as the changing trend of use of the respective secondary material in EEE manufacture.

As explained below (cf. response to question c.), the concentration of ATO used in flame retardant EEE components is determined by the required flame retardancy performance, measured with a standardized test (ISO 4589 and ASTM D2863). The level of performance required, and subsequent type and amount of flame retardant needed to achieve this performance, will be dependent on the 'natural' flame retardancy of the polymer the flame retardant is added to, and the final application the polymer is aimed to be used in. Because of cost- and energy-efficiency needs, producers of flame retardant polymers will logically avoid to use more flame retardant than what is technically needed.

Because ATO is mainly used as a flame-retardant synergist, its use trend will be directly related to the use trend of the brominated flame-retardant compounds it is used with. The use of ATO makes it possible to use less fire retardants in the materials, this way safeguarding not only the efficient flame-retardant activity but moreover keeping the same structural and functional characteristics of the material to be used. If less ATO would be used, more brominated flame retardants would be required, with a risk of negatively affecting the material's characteristics, and it actual practical and fire safety performance.

As regards the trend of use of secondary sources of ATO, this is currently very low but likely to increase, as long as the collection and sorting of flame retardant plastics continues to improve and the EU deploys measures to incentivize this practice. Such measures include:
- Efficient and effective collection of ATO containing materials, including EEE,
- Promotion of modern best available sorting techniques which enable to separate materials containing POP brominated flame-retardant compounds from those containing non-POP ones, and

- Establishing long-term targets on the recycling of additive containing plastics, to stimulate a positive climate to invest in and develop the appropriate solutions.

c. **Please specify in which applications diantimony trioxide is used as a material constituent, as an additive or as an intermediate and what concentration of diantimony trioxide remains in the final product in each of these cases (on the homogenous material level). If diantimony trioxide is used as a synergist flame retardant, please specify the brominated flame retardant with which it is used and at what concentrations they are applied.**

Electricity powers almost every aspect of lives, at home, at work, and at play. Wherever there is a need for electricity, there is also a need for plastics. Plastics enables the progress of EEE, making it safer, lighter, more attractive, quieter, more environmentally friendly and more durable[3].

As regards safety, plastic do not conduct electricity and protect users from the risk of electric shock. They are also poor conductors of heat and their use reduces the risk of burns for users. However, they are combustible, and to be made fire resistant, they require flame-retardant additives.

The term "flame retardant" refers to a function, not a family of chemicals. Flame retardants hence refer to a variety of substances that are added to combustible materials to prevent fires from starting, or to slow the spread of fire and provide additional escape time. The chances to actually escape also depend on the presence of fire alarms, sprinklers, and properly signaled exits. Flame retardants work with these additional factors to decrease the risks of personal and material. These are interdependent solutions to achieve maximized levels of fire safety.

There are more than 200 different types of flame retardants, which producers classify according to their major constituent elements. The elements determine their chemical reaction with fire and therefore their suitability in different applications. A variety of different chemistries, with different properties and molecular structures, act as flame retardants and these chemicals are often combined for effectiveness.

The function and effectiveness of each flame retardant will depend on their mode of action. Fire is a chemical reaction between oxygen and a fuel when heated to an ignition temperature[4]. This can be explained on the basis of the fire tetrahedron (Figure 1). The fire tetrahedron is a geometric representation of the four factors necessary for igniting and sustaining a fire[5]:

- Fuel – any substance that can combust, e.g. the plastic
- Heat – heat energy sufficient to cause ignition, e.g. generated from the electrical current
- Oxidizing agent – air containing oxygen
- Chemical chain reaction – sufficient reaction energy to produce ignition

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[3] Source: British Plastics Federation. Available from: http://www.bpf.co.uk/innovation/Plastics_in_Electrical_and_Electronic_Applications.aspx

[4] Source: The International Bromine Council. Available from: http://bsef.com/bromine-applications/fire-safety/

[5] Source: Fire action. What is the Fire Tetrahedron? Available from: https://www.fireaction.co.uk/news/fire-tetrahedron-explained/

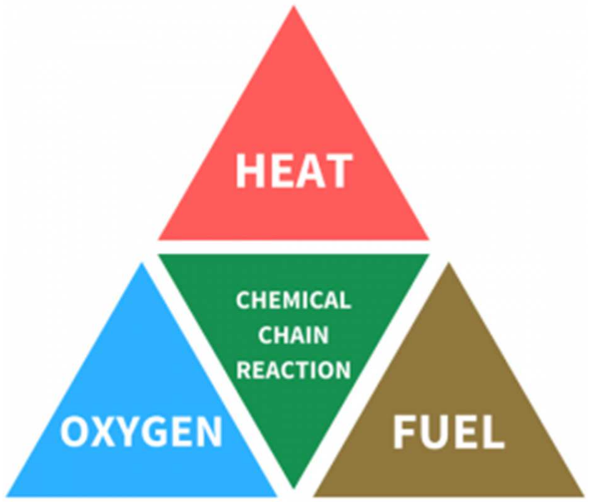

Figure 1. Fire tetrahedron

Because plastics are intrinsically combustible, and plastics in EEE are exposed to a source of heat, the fire-safe use of plastics requires the use of flame retardant additives, which will interfere with the chemistry of the flame and the related chemical chain reaction.

In the specific case of ATO, it 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 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 provide 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 cuts the supply of fuel to the combustion region, thereby ceasing the combustion chain reaction.

Because of the two flame retardancy mechanisms they facilitate, the combined use of halogenated flame retardants and ATO is known to provide the most performant flame retardant solution[6].

The amount of flame retardant needed will depend on two main factors:

i) the relative 'natural' resistance to burning of each plastic (which is determined by the chemical composition of each polymer, i.e. plastics which do not contain flame retardants have a varying ability to support combustion) – cf. Figure 2 below; and

ii) the minimum flame retardancy performance that is required for the specific use or application of the polymer.

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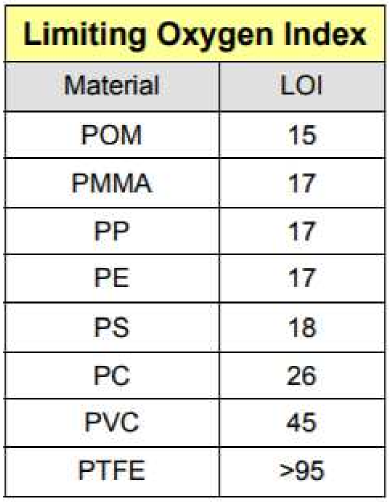
[6] Source: Kitano, M. 2016. Introduction to Flame Retardancy: Protect your life and property from fire. Published by: Osamu Odajima. Japan. Pages 33-46



Limiting Oxygen Index

Material	LOI
POM	15
PMMA	17
PP	17
PE	17
PS	18
PC	26
PVC	45
PTFE	>95

Figure 2. Examples of ‘natural’ resistance to burning for various polymers (without the addition of flame retardants)[7]

The flame retardancy performance can be measured with 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)

The LOI is a way of ranking the polymers (with and without flame retardants) based on combustibility. The LOI is measured by placing the samples in a flow of oxygen/nitrogen gas and increasing the concentration of oxygen until the sample will support combustion. As the normal amount of oxygen in air is approximately 21%, polymers with indexes below 21 will burn continuously at normal conditions. The next lowest oxygen concentration is the value used as the index. Materials with an LOI greater than the atmospheric oxygen concentration (> 21) are called fire retardant materials.

Looking at Figure 2 above, for PP (polypropylene), PE (polyethylene), or PC (polycarbonate) to be used in applications exposed to heat and to a risk of fire, they would require much more flame retardant than rigid PVC, which has an intrinsic high resistance to ignition (In the case of flexible PVC, which will contain variable quantities of plasticizers, the LOI is between 21 and 36). It is important to note that different polymers offer different properties; so, polymers with a low LOI may still be used in EEE (with the relevant addition of flame retardant additives), because of the other properties they provide. In the specific case of PVC, it may be used without flame retardancy when used away from heat sources but would require a minimum of flame retardants to be added to maximize its fire safety.

The flame retardancy of plastics is preferably determined by the UL 94 V method (Underwriters Laboratories Inc. Standard of Safety, "Test for Flammability of Plastic Materials for Parts in Devices and Appliances", p.14 to p.18, Northbrook 1998). The UL94 identifies a combustion or flame retardancy level after exposing the material to an open flame. The existing levels are (from lowest (least flame-retardant) to highest (most flame-retardant) are:

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[7] Zeus Industrial Products, Inc. 2005. Flammability of Polymers. Zeus Technical Whitepaper. Available from: http://www.appstate.edu/~clementsjs/journalarticles/zeus_flammability.pdf.

- HB: slow burning on a horizontal specimen; burning rate < 76 mm/min for thickness < 3 mm or burning stops before 100 mm
- V-2: burning stops within 30 seconds on a vertical specimen; drips of flaming particles are allowed.
- V-1: burning stops within 30 seconds on a vertical specimen; drips of particles allowed as long as they are not inflamed.
- V-0: burning stops within 10 seconds on a vertical specimen; drips of particles allowed as long as they are not inflamed.
- 5VB: burning stops within 60 seconds on a vertical specimen; no drips allowed; plaque specimens may develop a hole.
- 5VA: burning stops within 60 seconds on a vertical specimen; no drips allowed; plaque specimens may not develop a hole.

Each level refers to a preset specification for plastic materials for parts in devices and appliances and can be validated with a specific test method. For 5VA and 5VB ratings, the flame ignition source is approximately five times as severe as that used for testing the other materials. In practical terms, a UL94 V0 level is typically the highest flame-retardant level for the most common EEEs in scope of the RoHS Directive[8].

Another important test method is the glow-wire resistance GWFI (glow-wire flammability index) which is tested in accordance with DIN EN 60695-2-12 on plaques. The GWFI test is a general suitability test for plastics in contact with parts that carry an electrical potential. The temperature determined is the highest at which one of the following conditions is met in three successive tests:(a) no ignition of the specimen, or (b) after-flame time or after-glow time 30 s after end of exposure to the glow wire, and no ignition of the underlay.

Beyond the natural fire resistance of the polymer, the combined choice of polymer and flame retardants will be dictated by the technical functional, design, etc. specifications of the component of the EEE they will be used in. Table 3 provides an overview of the typical properties of the various polymers which can be used in EEE, and whether ATO can be expected to be present in these.

Table 3. Plastics commonly used in electric and electronic equipment[9]

Plastic	Properties	EEE article	ATO used?
Acrylonitrile butadiene styrene	Rigid, opaque, glossy tough, good low temperature properties, good dimensional stability and easily electroplated, low creep.	telephone handsets, keyboards, monitors, computer housings	Yes
Alkyd resins	Rigid, tough, heat resistant, good arc and tracking resistance, good long term, dimensional stability, fungus resistant, good color stability.	circuit breakers, switch gear	
Amino resins		lighting fixtures	
Epoxy resins	Rigid, clear, very tough, chemical resistant, good adhesion properties, low curing, low shrinkage.	electrical components	

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[8] Underwriters Laboratories. Available from: https://standardscatalog.ul.com/standards/en/standard_94_6.

[9] British Plastics Federation. Available from: http://www.bpf.co.uk/innovation/Plastics_in_Electrical_and_Electronic_Applications.aspx and http://www.bpf.co.uk/plastipedia/polymers/polymer-thermoplastics.aspx.

Plastic	Properties	EEE article	ATO used?
Polyurethane resins	Elastic, abrasion and chemical resistant, impervious to gases, can be produced in a wide range of hardness.	electrical potting compounds, and hard-plastic parts (e.g.: for electronic instruments)	Maybe?
Ethylene vinyl acetate	Flexible (rubbery), transparent, good low temperature flexibility (-70'C), good chemical resistance, high friction coefficient.	freezer door strips, vacuum lean hoses, handle-grips	
Phenol formaldehyde		fuse boxes, knobs, switches, handles	
Polyacetal	Rigid, translucent, tough, spring-like qualities, good stress relaxation resistance, good wear and electrical properties, resistant to creep and organic solvents.	business machine parts	
Polyamide	Rigid, opaque, high strength, exceptional thermal and electrical properties (up to 480'C), resistant to ionizing radiation, high cost.	food processor bearings, adaptors, transportation manufacturing industry, in automotive electronic applications	Yes
Polycarbonate	Polycarbonates are strong, stiff, hard, tough, transparent engineering thermoplastics that can maintain rigidity up to 140oC and toughness down to -20°C or special grades even lower.	telephones	Maybe?
Polyesters	PBT, PET and PBT Blends are engineering plastics with excellent processing characteristics and high strength and rigidity for a broad range of applications.	business machine parts, coffee machines, toasters	
Polyethylene	Flexible or rigid, translucent / waxy, weatherproof, good low temperature toughness (to -60'C), easy to process by most methods, low cost, good chemical resistance.	cable & wire insulation	Yes
Polymethyl methacrylate		hi-fi lids, windows on tape decks	
Polymethyl pentane	Rigid, tough, lightweight (density 0.83 gm/cm), chemical resistant, additives are required for outdoor use, highly permeable to gases, transparent crystalline material.	cable & wire insulation, circuit boards, microwave grills	Yes
Polyphenylene oxide	Rigid, opaque, good dimensional stability at high temperature and humidity conditions, difficult to process (blended to ease injection molding), tough.	coffee machines, TV housings	
Polyphenylene sulphide	Rigid, opaque non-burning continuous use at 240'C, good chemical resistance,	hairdryer grilles, element bases, transformers	

Plastic	Properties	EEE article	ATO used?
	good electrical insulator, moisture resistant, rarely used unfilled.		
Polypropylene	Rigid, opaque, good dimensional stability at high temperature and humidity conditions, difficult to process (blended to ease injection molding), tough.	cable & wire insulation, kettles	Yes
Polystyrene	Brittle (or hard), rigid, transparent (or translucid), low shrinkage, low cost, excellent X-ray resistance, free from odor and taste, easy to process.	refrigerator trays/linings, TV cabinets	
Polysulphone		microwave grills	
Polytetrafluoroethene	Semi-rigid, translucent, exceptional low friction characteristics, superior chemical resistance, impervious to fungi or bacteria, high temperature stability (260'C), low temperature toughness (-160'C), good weathering resistance and electrical properties.	electrical applications	
Polyvinyl chloride	Compatibility with many different kinds of additives - PVC can be clear or colored, rigid or flexible, formulation of the compound is key to PVC's "added value".	cable and wire insulation, cable trunking	Yes
Styrene acrylonitrile	Rigid, transparent, tough, resistant to greases, stress cracking and crazing, easily processed, resistant to food stains.	hi-fi covers	
Urea formaldehyde		fuse boxes, knobs, switches	

The polymer of choice for a given EEE application and its ‘natural’ fire-resistance vs the LOI or UL level necessary for that application will determine the type and amount of flame retardant needed. It is generally recognized that only the combination of halogen + ATO can achieve UL94 V0 flame retardancy.

In general terms, the amount of ATO added as flame retardant synergist will typically be in a 1:3 or 1:4 ratio to the bromine or chlorine content. Overall, ATO will be present in levels between 2 and 8% in flame retardant plastics.

Finally, the flame-retardant plastics will not be used in external components but in components exposed to heat and electrical current, which are typically distant from the users’ various possible exposure routes. There will hence be no exposure for the users during normal and foreseeable conditions of use.

2. Quantities and ranges in which diantimony trioxide is in use

This cannot be answered by i2a as it is addressed to specific companies using ATO.

a. Please detail in what applications your company/sector applies diantimony trioxide and give detail as to the annual amounts of use. If an exact volume cannot be specified, please provide a range of use (for example – 50-100 tonnes per annum).

b. Please provide information as to the ranges of quantities in which you estimate that the substance is applied in general and in the EEE sector. c. If substitution has begun or is expected to begin shortly, please estimate how the trend of use is expected to change over the coming years.

3. Potential emissions in the waste stream

a. Please provide information on how EEE applications containing diantimony trioxide are managed in the waste phase (with which waste is such EEE collected and what treatment routes are applied)?

Articles 5, 6 and 8 of the EU WEEE Directive foresee that EEE waste (WEEE) is collected and treated separately and adequately from other wastes in permitted facilities.
Annex VII of the WEEE Directive provides measures to guarantee the selective treatment for materials and components of waste electrical and electronic equipment referred to in Article 8(2) of the Directive, and foresees that plastics containing brominated flame retardants and external electric cables are to be removed from any separately collected WEEE.
In line with the implementation of the WEEE Directive at national levels, it can be reasonably expected that ATO containing WEEE will not be mixed with municipal or other wastes. This sorting is a first step to enable a separate treatment of ATO containing WEEE.

Moreover, the critical raw material status of Sb has recently sparked efforts to find secondary sources (within the European market) of antimony either through the recycling of end-of-life products or by recovering antimony from industrial process residues. Efficient recovery of antimony from plastics requires adapted screening and sorting methods to identify plastics with high antimony contents. X-ray fluorescence spectroscopy (XRF) provides a fast and non-destructive screening. Other interesting techniques are X-ray transparency and laser-induced breakdown spectroscopy (LIBS).

Once sorted, the antimony-containing plastics can be directly re-extruded (if no POPs are present) or can be placed in special ovens for the pyrolysis of the polymer (waste to energy), where antimony is caught in the residues (bottom ashes or fly ashes). The presence of ATO is not imposing any of these two routes; both are possible.
The gas mixture captured during the pyrolysis can be washed (under air-free conditions or by combustion) with an alkaline aqueous solution (e.g., NaOH), to obtain and separate out NaBr and ATO. Investigations show that under moderate oxidative conditions, the partition of antimony between the residual bottom ash (64 %) and the gas phase (36 %) is constant regardless of the temperature. However, at 850 °C, Sb is mainly present in the gas phase as Sb(III), while around 1100 °C, Sb(V) is favored.

Besides pyrolysis to recover the Br and Sb content in various chemical forms, the Br and Sb content of the polymers can also be extracted, to produce a > 95% Br and Sb free polymer that can be more easily recycled.

Possible solutions (of which some have considerable upscaling opportunities) are described in more detail by Dupont et al. (2016)[10].

As to ATO contained in PVC, it will follow the PVC recovery routes which have been developed with the support of the PVC industry. It includes a mechanical recycling of mixed plastic waste, the recovery of HCl and hydrocarbons which can be reused as feedstock to produce new PVC, incineration with energy recovery, and controlled landfill as final disposal of the non-recyclable fraction[11].

Whether made of PVC or other polymers, before or after initial shredding steps, plastics can be sorted on a transport conveyor belt, by optical scanners using camera systems that employ near-infrared (NIR) technology to analyze the reflected light, and sort material by color. X-ray fluorescence (XRF) technology is

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[10] Source: Dupont, D.; Arnout, S.; Jones, P.-T. ; and Binnemans, K. 2016. Antimony Recovery from End-of-Life Products and Industrial Process Residues: A Critical Review. J. Sustain. Metall. (2016) 2:79–103. Available from: https://link.springer.com/content/pdf/10.1007%2Fs40831-016-0043-y.pdf.

[11] Source: European Council of Vinyl Manufacturers. Available from: http://www.pvc.org/en/p/recycling-in-europe.

also used to sort mixed plastics by analyzing their molecular structure, enabling sorting by metallic content, to separate out bromine containing plastics, for example. Sorting by density always allows separation of flame retardant plastics, ATO even simplifies this action because of the weight it adds to the plastic. Sorting by density is done on shredded material in water/fluids with different densities.

When the flame retardant containing polymers are separated from other plastic streams, they can be: re-used in same applications (provided they do not contain restricted brominated flame retardants above restriction thresholds and a further chemical analysis is made, which most of the time would lead to separate ATO containing plastics from other plastics going to recycling to a great extent) and/or other plastic applications (less evident without sorting); taken forward for the recovery of specific metals (e.g. Cu wires) or the recovery of flame retardants as such or in the plastic (through processes such as creasolv, PSLoop or VinyLoop); reused as energy source; reused for catalytic cracking and re-use of additives; taken to incineration and landfill. All of these options are in a different phase of use/development.

The recovery of metals contained in PVC, such as (legacy) Pb, Cd, Ca, Zn, Sn or Sb can be done by a symbiotic reuse of PVC waste in non-ferrous metals smelters. In such smelters, the electronic scrap will be shredded and passed through air separation, screening, magnetic separation for iron, optical separation for Al and some alloys, and induction separation for plastic material. Shredding and separation take place in closed buildings. Sieves, as well as transfer points from one conveyer belt to another, are also typically closed or taking place under negative pressure. Sprinkling facilities to keep the shredded material wet (to prevent dust formation) are also installed. Conveyors for shredded material are vented and the exhaust gas is treated in a bag filter. The air from the air separation column can be treated in a cyclone. Dusty materials are stored and blended in under closed conditions too, or by front-end loaders. This ensures that no release (loss) of any (valuable) metal takes place during the pre-treatment. The waste phase of ATO containing EEE does hence not pose any environmental problem. Because of the presence of halogens and the increased risk of producing dioxins during treatment, electronic scrap processing will require extra environmental compliance equipment, typically in place at Cu, Pb and precious metals refineries.

An overview of the chemicals that can be recovered in an optimized metal recovery process is available in Figure 3. Precious metals (Silver, gold, platinum, palladium, ruthenium, rhodium, iridium and osmium) are very scarce metals that are present in various sources. In order to recover these strategic metals (some of which co-exist with Sb in EEE components and articles), Umicore will deploy a complex but efficient and effective material recovery process, starting from end-of-life articles (such as WEEE and other ‘recyclables’) and industrial by-products (e.g. valuable ‘leftovers’ of other production processes). Using the chemical affinity there is between metals, collector metals will be used to separate valuable metals contained in the recyclables and by-products, in order to be progressively separated and purified. Umicore recycles up to 17 different metals, including Sb, using currently available recyclables and industrial by-products of varying compositions.

Recyclables (including WEEE) and industrial by-products are sorted, pre-treated (e.g. crushed and/or shredded), and sampled to determine their (precious) metal content and general composition. Depending on their composition, they are fed to one or another smelting process. If the raw material is more likely to contain Pb or metals which are chemically ‘compatible’ with Pb, it will be directed to a Pb process (right side). If it is more likely to contain Cu or metals which are easily collected or carried by Cu, it will follow the Cu process (middle). The carbon content of the plastics can be used as reducing agent, in addition to other sources of fuel. Indeed, during the smelting of electronic scrap or battery scrap, the combustible plastic content contributes to the energy that is used in the smelting process and reduces the amount of fossil fuel that is needed.

The ATO containing raw materials can be fed into any of these processes. If it enters the Cu process, the Sb fraction will be removed from the Cu one through the Pb slag, that will be fed to the Pb process. If it enters the Pb process, it will be refined out of the Pb bullion coming from the Blast Furnace. The separation of Sb from Pb can be done by adding various reactants such as sodium, which will solubilize Sb in a fraction than can be further transformed and purified into ‘fresh’ Sb metal or Sb compounds, that can be used again in EEE or other applications, as the case may be.

Cu or Pb smelters/refineries may either recover and purify the Sb on-site or supply the Sb-containing fraction to another site, for further processing. The industrial symbiosis very much enables plastic and metals manufacturing sites to exchange the materials they cannot handle on-site, to ensure maximum recovery with the smallest environmental release or workplace exposure possible. Indeed, the recovery of Sb will take place under conditions of high emission controls to limit/minimize any risk of release of or exposure to ATO or Sb. Non-ferrous metals producing plants fall under the scope of the Industrial Emissions Directive (IED), and its associated Best Available Techniques Reference documents (BRefs) and Best Available Technique-Associated Emission Limits (BAT-AELs). As Sb is mostly present in Pb refineries, these are required to monitor Sb in stack emissions at least once per year[12].

All the evidence reported in the REACH Dossier for ATO demonstrates that it poses no risk for the aquatic compartment. The relevant extract of the CSR is provided as an Annex to this response (not for publication as constitutes proprietary information). Sb in water is monitored in 11 EU Member States and even with the lowest Predicted No Effect Concentration (PNEC) for drinking water, Sb leads to no risk to the aquatic compartment.[13] It can be readily expected that it would not represent a risk for air and soil either.

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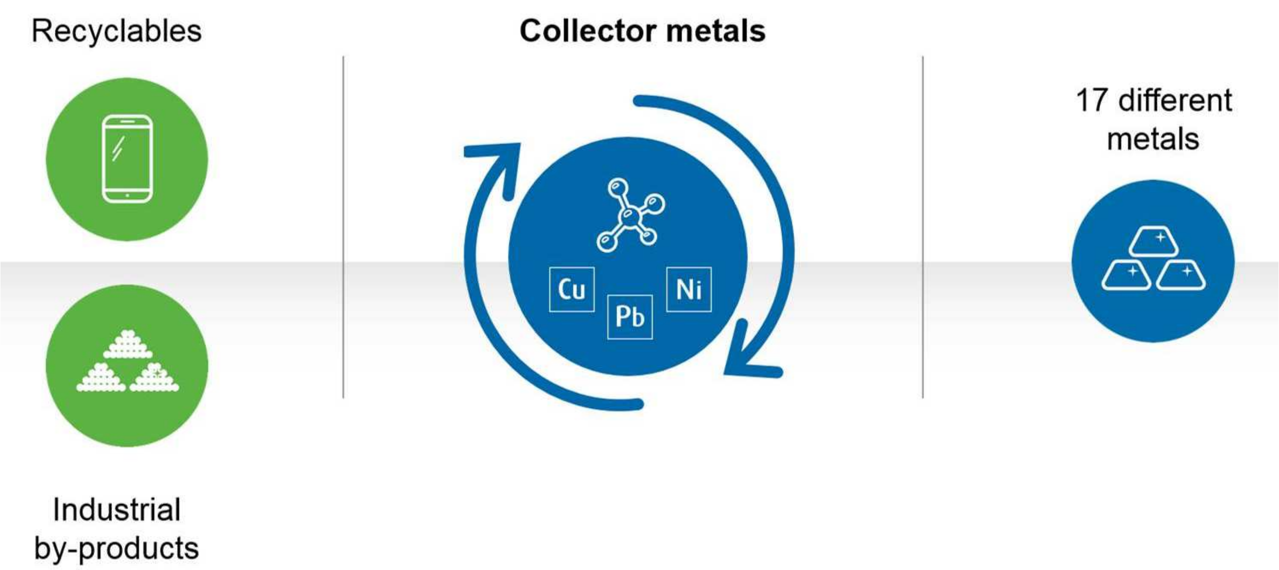
[12] Source: EU Joint Research Centre. Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries. Available from: http://eippcb.jrc.ec.europa.eu/reference/BREF/NFM_Final_Draft_10_2014.pdf (2014) and http://eippcb.jrc.ec.europa.eu/reference/BREF/NFM/JRC107041_NFM_Bref_2017.pdf (2017).

[13] Source: EU Joint Research Centre. 2016. Monitoring-based Exercise: Second Review of the Priority Substances List under the Water Framework Directive. Available from: https://circabc.europa.eu/sd/a/7fe29322-946a-4ead-b3b9-e3b156d0c318/Monitoring-based%20Exercise%20Report_FINAL%20DRAFT_25nov2016(1).pdf.



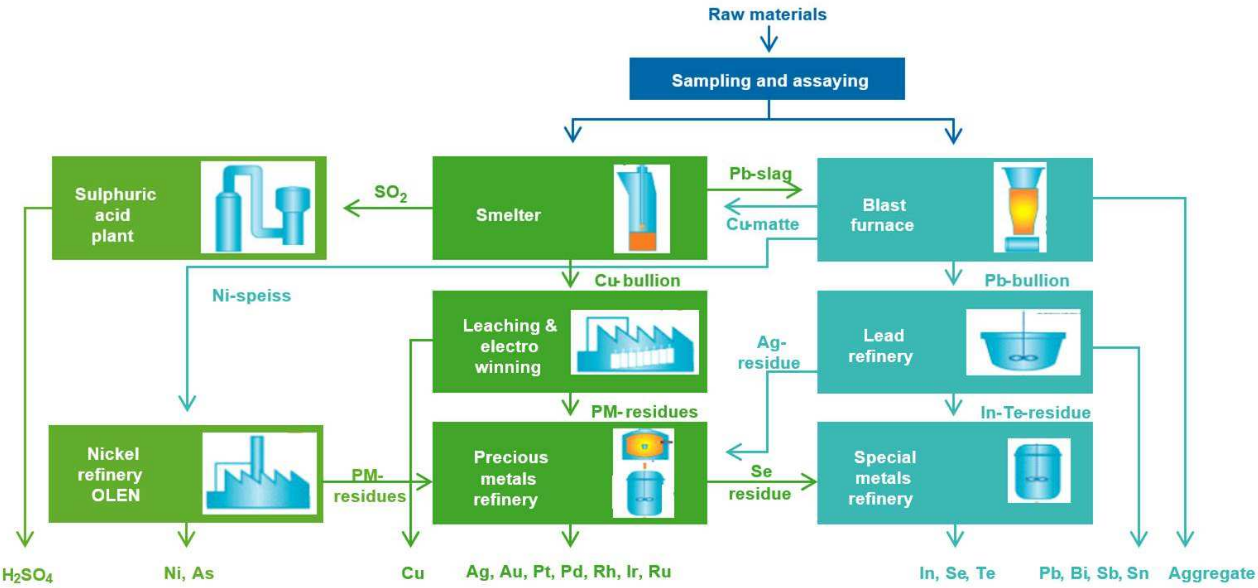


Figure 3. Umicore's metallurgical flowsheet enabling recovery of Sb from plastic waste, a.o.

b. How are waste wire and cables containing diantimony trioxide managed in the waste phase and how is copper extracted from such waste to enable recycling?

The sorting and recycling of wires and cables is stimulated by the need to recover the Cu contained in them. Their recycling will hence follow a similar process as the one described for the recovery of precious metals by Umicore.

There are different methods for recycling of wire and cable. In most cases, electric wires and printed circuit boards (PCB) are taken out before crushing/shredding operations. The wires 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.

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

The tonnage of recycled cables is increasing due to recycling of PVC. In 2016, 127 kTon of PVC cables were recycled (containing ATO) (Figure 4).

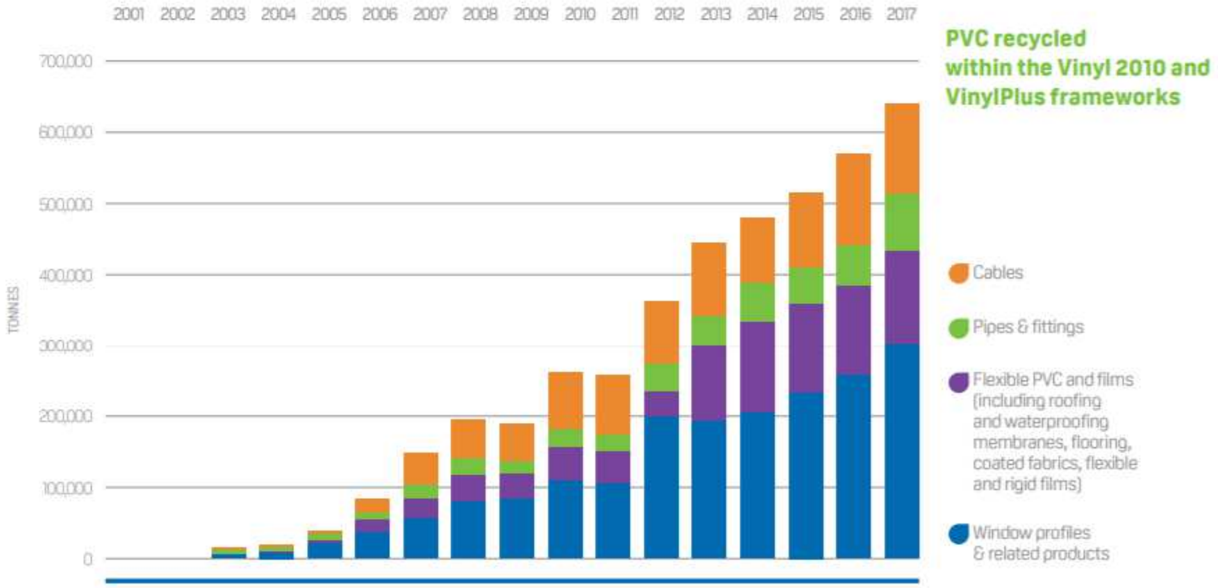


Figure 4: PVC recycled as part of the Vinyl 2010 and VinylPlus frameworks[14]

PVC cables are mostly recycled through classic mechanical recycling. Soft PVC in WEEE constitutes only a very small fraction of the overall amount of EEE waste, since it is primarily used in insulation of cables and wires[15], a finding consistent with an earlier report for the European Commission[16]. In fact, the fraction of soft PVC is so small that recycling of it from WEEE is generally not performed. In contrast, soft PVC benefits from a much higher share in the material obtained from cable reclamation. The material mix of these cables is generally about 60% metal and 40% plastic, the latter consisting of about 50 to 80% of PVC (depending on the cables processed).

The material is shredded/micronized further (if necessary) and then re-melted either into PVC compounds (with potentially the addition of specific additives such as color masterbatches) or directly into articles with the

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[14] Source: VinylPlus. 2018. Progress Report. Available from: https://vinylplus.eu/uploads/Modules/Documents/vinylplus-progress-report-2018.pdf.

[15] Source: Austrian UBA. 2013. Study for the Review of the List of Restricted Substances under RoHS2. 2nd Interim Report. Available from: http://www.umweltbundesamt.at/fileadmin/site/umweltthemen/abfall/ROHS/2nd_Interim_Report.pdf.

[16] Source: Rita Groß, R.; Bunke, D.; Gensch, C.O.; Zangl, S.; and Manhart, A. 2008. Study on Hazardous Substances in Electrical and Electronic Equipment, Not Regulated by the RoHS Directive. Available from: http://hse-rohs.oeko.info/fileadmin/user_upload/Documents/RoHS_Hazardous_Substances_Final_Report.pdf.

following main technologies: injection molding (professional footwear), compression molding (e.g. traffic management), and calendering (waterproofing membranes and sheets).

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.

A special solvent is used to dissolve the PVC waste selectively in a closed loop batch process under pressure. All the components of the original PVC formulation are recovered in the form of an aqueous suspension.

A first VinyLoop© plant, located in Ferrara (Italy), was built in 2001 to treat post-consumer PVC cable waste. In 2011, about 7500 t of waste PVC, mainly cables, were processed in the VinyLoop© Ferrara plant. Besides cables, trials are going on to demonstrate the feasibility of recycling other types of waste PVC.

CABLO, a subsidiary of the Aurubis Group, is specialized in the separation of metals and plastics, in particular in the recycling of cable production waste and cable scrap, contributing to the largest Cu recycling enterprise worldwide. In addition to recovering the brass, Al, Cu, Fe and Pb, CABLO also extracts the almost metal-free plastic components and makes them available for reuse. These products with excellent contour accuracy and surface finish are produced using an innovative injection molding technique which has been specially developed to recycle plastics (PVC, PE).

c. How are waste glass and ceramics containing diantimony trioxide dealt with in the waste phase?

The glass and ceramic will not contain ATO, so there is no risk of exposure to ATO during waste glass or ceramic treatment.

d. Please detail potentials for emissions in the relevant treatment processes.

The various techniques through which ATO containing EEE waste is treated and their associated potential emission pattern are:

- Sorting techniques (NIR, XRF): waste in its original form/unchanged, solid; no emission
- Sorting based on density: done in liquid, water; liquid is filtered after sorting: no emission
- Creasolv/Vinyloop: done in liquid; without significant emission
- Shredding: due the WEEE Directive, the shredding will be done by authorized recyclers. Installations are closed, and combined with dust extraction and filter; controlled emissions only
- Melting: All established smelter work according to BRef. For Cu smelters, the limit value for total dust emissions is typically 5 mg/Nm3. In most cases, because Sb does not pose any major environmental concern, there is no specific limit value for Sb. However, the following rule is applied to control emissions to air: the sum of Hg, Th, Pb (max. 0,5 mg/m3), Co, Ni (max. 0,2 mg/m3), Se, Te, Sb, Cr, CN, F, Cu, Mn, V and Sn must not be higher than 2 mg/m3. But in actual operation the total dust emissions are measured continuously and can be even below 1 mg/m3.
- Thermal cracking/pyrolyze: processes are equipped with filter installations; controlled emissions only.
- Waste to energy or waste incineration plants: equipped with dust filter; controlled emissions only.
- As regards material that is landfilled, strict composition and leaching limitations are imposed before a material can be landfilled.

As to the workplace exposure, there are various national OELs for Sb, at 0.5 mg/m^3. This ensures that workplace exposure will be either very low (because of the same reasons mentioned for the description of the environmental emissions above) or controlled below the OEL.

Dust-free ATO products are available on the market. In these products, the ATO powder is incorporated into masterbatches (polymer pellets or grains which contain the ATO in an embedded manner), dispersions, or wetted. These solutions prevent downstream EEE facility operators to be exposed to ATO. The European ATO producers have already transformed more than 50% of their market share into these safe formats. In the EEE market almost all ATO is supplied in a safe “granulate” format.

In the production of ATO the exposure would be controlled below the OEL and further minimized through the necessary technological, hygiene, protective and surveillance measures. Further down in the supply chain, the manipulation of ATO will be to “granulated” forms or automatized, with no or minimum human intervention.

During recycling, although the shredding may release dust, antimony in that dust would be expected to be encapsulated in the plastic matrix, and the size of the dust would be far above the respirable size (i.e. > 4 µm, which is the particle size which has led to lung toxicity in rodents).

As risk is a combination of hazard and exposure, considering that ATO has a relatively low potency (high concentrations are needed to show an adverse effect), and that exposure will unlikely reach the high concentrations required to trigger an adverse effect, the risk related to the production, use or recycling of ATO is expected to be very low or inexistent. This has been demonstrated for all uses in the REACH Dossiers and the relevant Exposure Scenarios.

4. Substitution

a. For which applications is substitution underway?

i. For which applications is substitution scientifically or technically not practicable or reliable and why?

One of the assets of ATO is its affordable cost. When the price of ATO (which is very much related to the cost of Sb metal) rose from 6000 $/pound in 2009-2010 to 14000 $/pound in 2011-2012, a number of applications found alternatives to substitute for ATO (and other Sb substances). Industry firmly claims that the continued use of ATO despite this prohibitive increase in price demonstrates that for applications were no substitution occurred at these times of prohibitive prices, it will very unlikely occur at current ATO prices (around 8500 $/t). This shows that the technical substitutability of ATO will work hand in hand with the proper economic feasibility of any alternative (vs ATO).

Substitution is technically not possible where only the addition of ATO (e.g. in PVC) or the addition of brominated flame retardants with ATO (in other plastics), can meet the specifications of the EEE component, which combine heat and fire resistance, as well as dimensional stability, flexibility, hardness, wear, friction, abrasion and chemical resistance, etc. For example, some performant flame retardants have a plasticizing/softening effect on polymers, which is not compatible with some uses in EEE.

ii. Please specify in this respect which alternatives are available on the substance level (substitution) and which are available on the technological level (elimination). For example, which alternatives can be applied instead of diantimony trioxide used in PVC cables or in plastic components and which alternative isolating materials can be applied instead of PVC in order to eliminate the need for diantimony trioxide in such applications?

Substitution is the replacement of a substance or material, a product or article, a process or technology, by an alternative which maintains the same function or use, while bringing one or more possible improvements. Analyses of alternatives (AoA) and substitution processes have been implemented for decades for a number of reasons. Informed substitution decisions entail a comprehensive comparison of substances, or technologies, to be substituted, against their potential alternatives, covering their whole life-cycle, in a holistic manner[17].

First, it is clear that EEE needs to be built with polymers, which provide the lightest and most flexible design solution. The technological replacement of polymers in EEE can hence not be envisaged.

Second, as various parts of EEE made out of polymer are exposed to a source of heat and are relatively easily combustible, the total elimination of flame retardants in EEE polymers is not an option either.

Third, if the choice of flame retardant was to be discussed, this would have to be done for every single EEE component, which needs to meet specific physical, chemical and flame retardancy technical specification and/or fire-safety requirements. It will be extremely challenging and nearly impossible to come up with solutions which will meet both the requirements of UL94 V0 and the color, weight, and mechanical functional specifications.

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[17] Source: Cross-Industry Initiative for better regulation in chemicals management. 2016. Synergies between REACH and workplace legislation: Improved analysis of alternatives and substitution. Available from: file:///C:/Users/Caroline/Downloads/Substitution_updated%20(30%2005%2018)%20(1).pdf.

Whatever halogen-free trends and restrictions of certain flame retardants will hence never fully overrule the intrinsic combustion potential and technical mission of EEE polymers, which will require, despite these trends and restrictions, to continue using the most technically performant solution.

Each type of flame retardant will operate according to a specific mode of flame retardancy action. This is why using a combination of flame retardants increases the performance of the flame retardancy. There are two conditions to be met to achieve the (highest) necessary flame retardancy:

- The decomposition behavior of the flame retardant must match that of the polymer when combusted: for example, if the decomposition of the flame retardant yields low molecular weight compounds, this would be incompatible with a system where decomposition of the polymer is controlled by the supply of radicals.
- The decomposition temperature of the flame retardant and the polymer must be compatible: the most effective combination is a flame retardant which starts to decompose at temperatures 60-75 °C lower than the decomposition temperature of the polymer + a flame retardant which starts to decompose, with about 50 % of the polymer decomposing[18].

The above criteria will vary depending on the chemical nature and physical form/size/aspect ratio of the polymer, resin or rubber that needs to be made flame retardant. There is hence no 'one-fits-all' solution.

In any case, it is not correct to compare existing solutions with potential alternatives, which are by far less investigated than the existing solutions, which are handled with the applicable safety measures.

Unsolicited restrictions generate market uncertainties that put pressure on companies who aim to remove the listed substances from their portfolios, inventories and supply chain as quickly as possible. Although such reactive behavior may seem honorable and wise, in practice, decisions taken under such pressure may precipitate 'regrettable substitution'. Regrettable substitution is not only the substitution of a substance or a technology by an alternative which may actually pose similar or worse risks, but also the substitution by alternatives which are unsustainable from an energy consumption, sourcing, or resource efficiency standpoint for instance, and which shift or transfer the risk elsewhere.

Such regrettable substitutions do not bring an overall added-value for human health and the environment when the substance was initially used safely. They may actually trigger additional or worse problems than those originally posed by the targeted substance or technology. For a substitution to be successful, it must be the result of an informed, well-thought and documented AoA exercise including: a comprehensive comparison of substances or technologies to be substituted against their potential alternatives, on an equal footing, covering their entire life-cycle, in a holistic manner[19].

In the specific case of ATO used in flame retardant materials necessary for safe EEE applications, possible alternatives and successful substitution requires:

- An equivalent or comparable amount and quality of data on the hazard and exposure & emissions situation (not only actual levels, but measures in place to prevent, minimize or control these) of ATO and its possible alternatives.
- An equivalent or comparable amount and quality of data on the life-cycle of ATO and its possible alternatives, from extraction to disposal and/or recycling, accounting for resource conservation, energy and carbon footprint, environmental, social and economic impact, etc.

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[18] Source: Kitano, M. 2016. Introduction to Flame Retardancy: Protect your life and property from fire. Published by: Osamu Odajima. Japan. Pages 33-46

[19] Source: Cross-Industry Initiative for better regulation in chemicals management. 2016. Synergies between REACH and workplace legislation: Improved analysis of alternatives and substitution. Available from: file:///C:/Users/Caroline/Downloads/Substitution_updated%20(30%2005%2018)%20(1).pdf.

- An equivalent efficiency and effectiveness in flame retardancy performance without adversely modifying the technical properties of the polymer, resin or rubber, or those of the EEE component it will be used in.

The International Antimony Association is not aware of any specific AoA which has been done in such a holistic manner and which could provide indications of a potential for successful (as opposite to regrettable) substitution of ATO in EEE.

iii. What constraints exist to the implementation of the named substitutes in a specific application area (provide details on costs, reliability, availability, roadmap for substitution, etc.). For example, for what range of the diantimony trioxide applications can specific substitutes be used for?

Technical specifications of the EEE components are the main (justified) constraint to implement substitutes for fame retardancy in EEE.

The absence of a truly holistic AoA is the second main constraint to (successfully, and not regrettably) implement substitutes for flame retardancy in EEE.

5. Socio economic impact of a possible restriction

Please provide information as to the socio-economic impacts of a scenario in which diantimony trioxide were to be restricted under RoHS. Please specify your answers in relation to specific applications in which the substance is used and/or in relation to the phase-in of specific alternatives in related application areas. Please refer in your answer to possible costs and benefits of various sectors, users, the environment, etc. where possible; please support statements with quantified estimations.

As stressed earlier in the introductory statement, it is important to note that any restriction on the use of ATO in flame retardant applications, which is the chief use of ATO and Sb substances in terms of volume, may negatively affect other societally indispensable uses of ATO. The volumes of ATO needed in flame retardancy solutions renders many other key applications and recycling solutions economically feasible. Any limitation in the use of ATO as a flame-retardant synergist will trigger an automatic cascade of changes to the larger ATO and Sb substances market. If the use of ATO as flame retardant synergist in EEE somehow decreases or stops due to a RoHS restriction, the viability of important applications in other markets (e.g. specialty glass, medicine, nuclear industry and technical alloys) would immediately be challenged too. If the use and hence production of ATO (or Sb substances more largely) decreases, the continued uses will be possible at prohibitive costs only, and there will be a considerable shift to increased disposal of valuable resources containing Sb and other substances because there would be no viable markets for these anymore (it would be cheaper to dispose of them than to refine and purify them to meet the customers' use specifications). This would go against Europe's Circular Economy goals.

In order to visualize the relative importance and interdependence of ATO and other Sb substances and uses, the following high-level figures are provided:
World Sb resources have been estimated at 5 million tons in 2011 by Bio Intelligence Service[20]. According to USGS, world Sb reserves amounts 2 million tons, of which 80% is concentrated in three countries (China (48%), Russia (18%) and Bolivia (16%)[21].

The annual world mine production of Sb is about 175,500 tons (BGS, 2015), of which 86% is extracted from China (78%), Russia (4%), and Tajikistan (4%). Sb is furthermore a co- or by-product of the production of Au, Pb, Zn and Cu.

Major global end uses of Sb include: Flame retardants, Lead-acid batteries, and Lead alloys (cf. Figure 5). Other sectors also depending on Sb substances include: PET, polyester, PVC, technology glass, pigments, ceramics and enamels, and pyrotechnic.

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[20] Source: Bio Intelligence Service (2015). Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials – Final Report. Prepared for the European Commission, DG GROW.

[21] Source: USGS (2016). Mineral Commodity Summary. Sb [online]. Available at: https://minerals.usgs.gov/minerals/pubs/commodity/Sb.

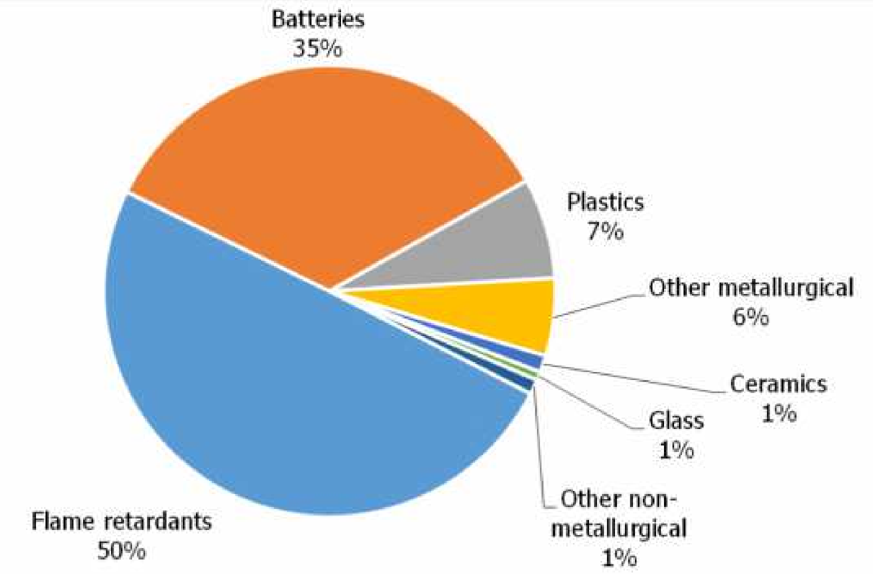

Figure 5: Global consumption/end uses of Sb[22]

In all applications, only relatively small quantities of Sb are needed to achieve the required function. But even in such small quantities, Sb enables the availability and performance of significant quantities of articles which are indispensable to society: flame retardant textiles, heat-stable plastics (43 million tons in 2015[23], PET resin (27.8 million tons in 2015[24], polyester textile, lead-based batteries (demand of 478 million KVAh in 2014[25]), lead-based alloys, high purity and transmission flat glass (global photovoltaic glass consumption attained 580 million m² in 2015[26]), to name only a few.

In the EU, the main application of Sb compounds is flame retardants, specifically ATO. Main producers of ATO are in Belgium, France, Spain and Italy. The total production of ATO in the EU is of about 20000 t/a, from which 2000 to 6000 t/a are exported outside the EU. EU furthermore imports 4000 to 8000 t/a of ATO from non-EU sources.

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[22] Source: Roskill (2014). Sb: Global Industry, Markets & Outlook [online]. Available at: https://roskill.com/market-report/Sb/.

[23] Source: PlasticsEurope (2016). World Plastics Materials Demand 2015 by Types. PlasticsEurope Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH [online]. Available at: https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf.

[24] Source: PlasticsInsights (2016). Global PET Resin Production Capacity. Editorial Team in Material Market, Plastics Insights [online]: Available at: https://www.plasticsinsight.com/global-pet-resin-production-capacity/.

[25] Source: PRNewswire (2016). Global and China Lead-acid Battery Industry Report, 2015-2018 [online]. Available at: http://www.prnewswire.com/news-releases/global-and-china-lead-acid-battery-industry-report-2015-2018-300200529.html.

[26] Source: Globe Newswire (2017). Global and China Photovoltaic Glass Industry Report 2016 - 5 Global and 18 Chinese PV Glass Companies. Research and Markets, Globe Newswire [online]. Available at: https://globenewswire.com/news-release/2016/08/03/861195/0/en/Global-and-China-Photovoltaic-Glass-Industry-Report-2016-5-Global-and-18-Chinese-PV-Glass-Companies.html.

The uses of ATO can be divided by their end use application in the sectors: electronic & electrical appliances, construction, wire & cable, automotive, textiles and others. Flame retardant plastics dominate over flame retardant textiles (cf. Figure 6 below).

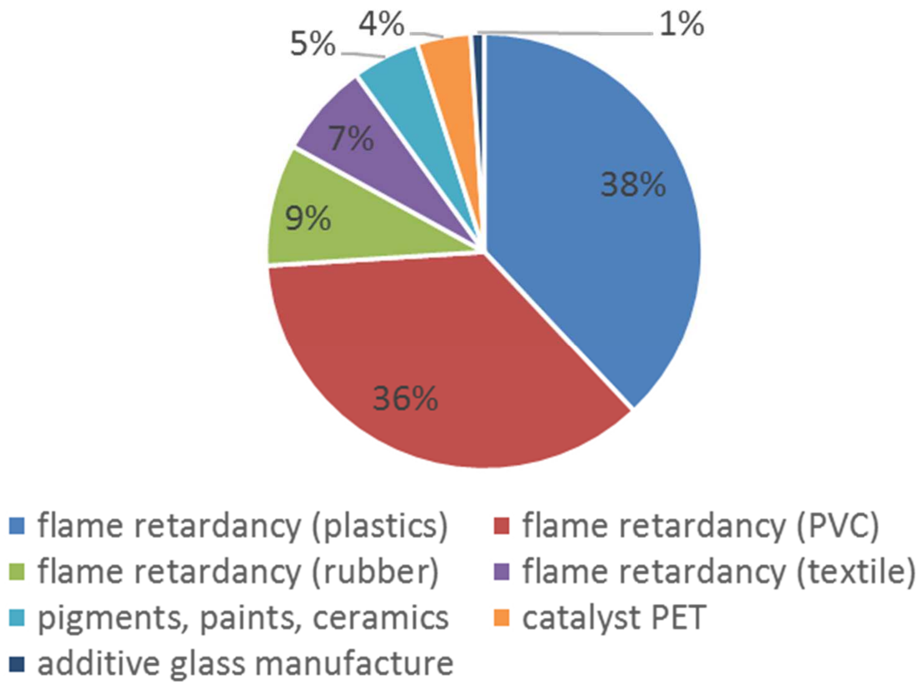

Figure 6: EU Use sector of Sb substances[27],[28]

Any change in the use volumes or conditions of ATO will automatically have negative economic repercussions on transportation costs, storage and distribution costs, sampling, testing and monitoring costs, marketing costs, licence fees and other overhead costs, which will be more difficult to write off when smaller volumes are marketed. This may reduce the number of suppliers on the market for which ATO production and trade can still be affordable and profitable, and decrease fair competition conditions due to the concentration of the supply with one or a few actors, making ATO and other Sb substances prices increase further and become even less accessible than what they currently are (cf. Sb is already considered as one of the most critical raw materials specifically because of the high dependence of few concentrated non-EU sources).

In more practical/using company terms, considering the very large number of specific applications of ATO in flame retardant components of EEE, the continued use of ATO despite the possible RoHS restriction would stretch the financial, human and time resources needed to investigate, test, and ensure compliance and compatibility, and finally validate potential new combinations of flame retardants in the event of a restriction of ATO under RoHS. Many exemptions would be required (which also entails high administrative, legal and technical costs), and in most applications, alternatives would either be implemented at the detriment of the functional quality or of the cost of the EEE.

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[27] Following a significant price change in 2011, Sb substances were replaced by alternative substances in some uses. But the overall proportion of uses remains as per the 2008 situation.

[28] Source: European Commission (2008). European Union Risk Assessment Report: Diantimony Trioxide. Office for Official Publications of the European Communities. Italy. 552 p.

6. Further information and comments

The information compiled on diantimony trioxide for the stakeholder consultation has been prepared as a summary of the publicly available information reviewed so far. If relevant, please provide further information in this regard, that you believe to have additional relevance for this review, as well as references where relevant to support your statements.

It is important to note that the presence of ATO in flame retardant plastics not only does not constitute an obstacle to recycling, but actually can be used to sort out brominated flame-retardant plastics from other (flame retardant) plastics, using density and weight. There is an increased potential to improve the recyclability and subsequent resource-efficiency and circularity of flame retardant plastics when these contain ATO.

As regards environmental issues, Sb is indeed mentioned in various legislations, despite the recent risk assessments have demonstrated that Sb is not toxic for the environment.

As regards human health, only animal data exists that shows lung toxicity, under extremely high exposure conditions. Levels of exposure below the OEL of 0.5 mg/m^3 have led to the absence of lung toxicity in workers producing and using Sb substances. In addition to workplace controls, ATO is supplied in a variety of non-dusty forms, such as wetted pastes, masterbatches, etc.

About i2a

The mission of the International Antimony Association is to inspire product stewardship along the antimony value chain. This mission is accomplished by generating and sharing information concerning the environmental and health safety and societal benefits of antimony and antimony compounds. Through a common evidence base, i2a promotes a harmonized risk management and continued safe use of antimony and antimony substances across the value chain and geographical borders.

For further information: www.antimony.com.