Reduction of emissions of POPs from waste treatment of electronic and electrical equipment, furniture and car interiors

Informal document prepared by the Netherlands

A. Introduction.

Flame-retardants are widely used in many products to improve the safety of the users. In the past decades brominated and chlorinated flame-retardants have been used. From these substances c-PentaBDE, c-OctaBDE and SCCP's are regarded as POPs and these were proposed for addition to the POP Protocol. Also PFOS has been used to improve certain characteristics of these products.
The main products containing these POPs are Electronic and Electrical Equipment (EEE), like business machines and computers, but also furniture and car interiors. After service life a large part of these products is processed as waste and shredded, before being recycled, incinerated or land filled. In the process of waste handling and shredding emissions of POPs can occur at a much higher level than the emissions during service life or production. These emissions can be controlled and reduced.

At the 41st meeting of the WGSR in April 2008 it was suggested to add waste treatment facilities of EEE, furniture and car interiors as a new source of emissions of POPs to Annex VIII of the POP Protocol. BAT for this source could be added to Annex V of the POP Protocol. The WGSR asked for more information about these activities and, especially, on the emissions of brominated or chlorinated flame-retardants and of PFOS caused by waste handling and on the costs and effectiveness of emission reductions.

In this document information is given on the emissions from waste treatment (part B.), on techniques to reduce these emissions (part C.) and on the current policies and legislation (part D). Furthermore, a draft text proposal on BAT for waste treatment facilities of EEE, furniture and car interiors is suggested in the conclusion section (part E.).
Not much data is available on the use of c-PentaBDE, c-OctaBDE and SCCP’s as flame-retardants. Because most data are available for c-PentaBDE this document will focus on this substance.
The name ‘c-PentaBDE’ is used, designating the commercial mixture of BDE congeners, that is known as ‘PentaBDE’, and that consists of pentaBDE and several other congeners.

B. Emissions from waste treatment facilities

To make an estimate of the relevance of emission abatement of this source, information is needed on the amount of POPs that can be released from waste treatment and to compare this with the overall emissions.
The following information could be retrieved from open sources.

1. Amount of flame-retardants in products in use today

The amounts of c- PentaBDE and of c-OctaBDE that are used as flame-retardants are declining. In most of the UN ECE region the use of these substances was terminated in the period between 2000 and 2008 (ref. 1). The EU Directive on restriction of hazardous substances (2002/95/EC) banned the use of c-pentaBDE in new electrical and electronic equipment after June 2006. No information about the use of c- PentaBDE or c-OctaBDE in Asia could be found. These flame-retardants might still be used in China and India where many EEE and other products are manufactured

The amount of c-PentaBDE used worldwide is estimated at 7500 metric tonnes per year (ref 1). Part of the total amount of c-PentaBDE has been used as flame retardant in products that are still in use today. There are no specific data about the amount of c-PentaBDE used in EEE.
The BSEF estimates that in 2000 56% of all Brominated Flame Retardants (BFRs) were used in EEE (ref. 2) If this division is also correct for c-PentaBDE the yearly use in EEE worldwide was 7500 x 0,56 = 4200 tonnes per year.
C-PentaBDE was also used in other products, mainly furniture and car interiors. This will account for a part of the other 44% of the BFR production that is not used in EEE.

In the EU Risk Assessment Report for PBDE the total amount of c-pentaBDE present in the EU-15 in the year 2000 was estimated to be 1100 tonnes/year (ref 12).

2. Emission sources in waste treatment after service life

The most important emission sources are the processes to prepare the waste for reuse, incineration or land filling. This involves transportation, dismantling, crushing, shredding and storage. These activities are carried out in waste treatment facilities.
For EEE waste these are in many cases specialised facilities, aimed at reusing certain components of the waste, or at recycling the contents of the materials used like precious metals (gold, silver, copper) or engineering plastics.
For car interiors the waste treatment is part of a recycling process. The metals in cars are recycled. The plastics and other components are shredded, into a product called ‘fluff’. The BFRs in car interiors will be partly released during the shredding process. Most of the BFRs will end up in the fluff. This fluff is land filled or incinerated.
There is no specific waste treatment process for furniture. Furniture is being land filled or incinerated, sometimes after crushing or shredding.

A specific type of waste is sludge from sewage treatment plants (STP's). A study in Norway (ref 10) showed that STP sludge can contain considerable amounts of BFRs. This could be caused by loss of BFRs during service life of products. The handling and disposal of STP sludges is not elaborated further in this document.

3. POPs released during waste treatment

The total amount of EEE waste in the USA in 2006 was estimated to be about 1.9 to 2.2 million tons (ref 4). This is about 7 kg per capita per year. For Switzerland the total amount of EEE waste is estimated to be 10 kg per capita per year (ref 5). For the

Netherlands the amount of waste from electronic equipment was estimated at 8,8 kg per capita per year (ref 6).
In 2007 147 000 tonnes of WEEE were collected in Norway. This equals about 32 kg per capita (see: http://www.sft.no/artikkel____42601.aspx?cid=10619 , ref 11.). However, the Norwegian regulation has a wider scope than the WEEE directive, all EEE are included. If the scope of the Norwegian regulation is limited to the scope of the WEEE directive the amount of EEE will be about 16 kg per capita.
The yearly amount of EEE waste produced in the UN ECE region is estimated to be 10 kg per capita.

The amounts of BFR in EEE waste treatment have been determined at waste treatment facilities in Switzerland in 2003. The amount of pentaBDE measured in EEE was 34 mg/kg of waste (ref. 3.). For this survey it is assumed that this value is representative for waste in other UN ECE countries.

The total amount of c-pentaBDE in EEE waste can be estimated assuming a production of 10 kg EEE waste per capita per year, containing 34 mg/kg c-PentaBDE. The total population in the UN ECE region being about 1 billion persons, this contributes to a possible yearly amount of 340 tons of c-PentaBDE for the whole UN ECE region in EEE waste.
This is an order of magnitude below the global estimate of 4200 tons based on the worldwide yearly use of c-PentaBDE.

C-pentaBDE is also used in other products. Furniture is incinerated or land filled after service life. Emissions of BFR will be relatively low.
Car interiors consist of plastic panelling, dashboards and upholstery. In most cases these materials are shredded and recycled, incinerated or land filled. Due to the shredding process the emissions of BFRs, attached to dust, can be a relevant source.

On the basis of the amounts of c-pentaBDE in products in use it is estimated that the possible amounts of c-pentaBDE in waste from products will be in the range of 400 to 4000 tons per year for the UN ECE region. Most of this c-pentaBDE in products will end up in a landfill or will be destructed in an incinerator. A part of this amount will be released to the environment, mostly to air, bound to particulate matter.

In the EU Risk Assessment Report (ref. 13) on pentaBDE the total emissions to the environment during disposal of products containing pentaBDE is estimated at 2% of the c-pentaBDE content. Air emissions are estimated at 0,1 %. For the case of EEE products and car interiors this estimate is probably too low. This is indicated by the high levels of BDE congeners that were measured in waste dismantling and recycling facilities (ref 13).
It is important to notice that waste from car interiors and EEE is being shredded or scrapped, during which heavy mechanical forces and elevated temperatures can lead to increased emissions of c-pentaBDE.
In this survey it is estimated that the emissions to air from waste treatment of EEE and car interiors are 1% of the c-pentaBDE content. As more than half of the c-pentaBDE is

used in these products the emission factor of 1% will be used in general for waste treatment of all products containing c-pentaBDE.

If the amount of waste per year is the same as the amount of new products the amount of c-pentaBDE in waste from products in the UNECE will be in the range of 400 to 4000 tonnes yearly.
This could lead to a yearly emission of 4 to 40 tons of c-pentaBDE due to waste treatment.

In the EU Risk Assessment Report (RAR) the total yearly emissions to the environment of c-pentaBDE is estimated for the EU-15 region at 43.2 tonnes (ref. 13). Of this amount 43 tonnes were attributed to emissions during service life and 0,2 tonnes to production of articles containing c-pentaBDE. TNO (ref 12) has estimated a total emission of 9,8 tonnes per year for the UN ECE region, mainly due to product use and solvent use. In the EU RAR and the TNO study the air emissions are probably underestimated.

The emissions to air from waste treatment are estimated to be in the range of 4 to 40 tonnes per year. This is in the same order of magnitude as the total emissions of c-pentaBDE to the environment. This indicates that waste treatment of EEE and car interiors can be an important source of emissions of c-pentaBDE to air. The emissions are probably higher or in the same order of magnitude as emissions during service life. As more products reach the end of their service life in the future the waste treatment of car interiors and EEE will probably be the largest source of emissions of c-pentaBDE to air. The relative contribution of furniture will be lower as this is not mechanically treated.

For c-octaBDE a similar estimate can be made. The measured emissions in the waste survey are 15 times the amounts of c-pentaBDE (ref 3). The BSEF estimated the yearly use of c-octaBDE however to be half of the use of c-pentaBDE (ref 2). The European Commission estimated the amount of c-octaBDE in waste to be 1316 tonnes per year for 1999 for the EU-15 (ref 7.). For the total UN ECE region this can be about 2 times higher (based on population), which would add up to 2600 tonnes per year.
If air emissions are estimated at 1% this could lead to a yearly emission of 260 tonnes of c-octaBDE due to waste treatment.

For SCCP data are lacking on the amounts used as flame retardant or additive to plastics. It can however be expected that also for SCCP’s waste treatment can be a relevant source of emissions.

Conclusion
In the next decade waste treatment of car interiors and EEE is expected to be the most important source of emissions to air of c-pentaBDE in the UN ECE region. Emissions are estimated to be in the range of 4 to 40 tonnes yearly.
Waste treatment of car interiors and EEE is also expected to be the most important source of emissions to air of c-octaBDE. Emissions are estimated to be up to 260 tonnes yearly.
The situation for SCCP’s is unclear but waste treatment could also be a significant source.

C. Abatement techniques, reductions and costs

This chapter deals with possible techniques to reduce emissions of waste treatment facilities, the achievable emission reductions and their costs. The given information has also been retrieved from open literature.

4. Technical options for emission abatement and efficiency of abatement techniques
The technical options for emission abatement are based on control of emissions and cleaning of the off-gases. This is described in the European BAT Reference document (BREF) for the Waste Treatment Industries (ref 8). This document gives information about the Best Available Techniques (BAT) to reduce emissions to air from waste treatment plants (ch 5.2 of the BREF). For reducing emissions to air from waste treatment (WT) plants treating EEE waste, furniture or shredded car interiors the following measures are presented as BAT in the BREF:

> BAT is to
> - perform crushing, shredding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment when handling materials that can generate emission to air (e.g. odours, dust, VOC's)
> - perform washing processes considering:
>   a. identifying the washed components that may be present in the items to be washed
>   (e.g. solvents)
>   b. transferring washings to appropriate storage and then treating them in the same way
>   as the waste from which they were derived
>   c. using treated wastewater from the WT plant for washing instead of fresh water. The resultant wastewater can then be treated in the WWTP (waste water treatment plant) or re-used in the installation.
>
> To prevent or control the emissions mainly of dust, odours and VOC and some inorganic
> compounds, BAT is to:
> - correctly operate and maintain the abatement equipment, including the handling and treatment/disposal of spent scrubber media
> - reduce air emission to the following levels:

Air parameter	Emission levels associated to the use of BAT (mg/Nm3)
VOC	7 – 20
PM	5 – 20

The emission levels mentioned in the European BREF can be attained by installing common emission abatement techniques like bag filters or, in some specific cases, scrubbers. The emission reduction efficiency of bag filters is 99% or more for particulate matter (PM). The efficiency of scrubbers for reducing emissions of particulates is in the range of 80% and more for PM. As the BFRs are bound to particulates these reduction efficiencies also apply to the reduction of BFR.

5. Achievable emission reduction and other environmental benefits

The total emissions of c-pentaBDE due to waste treatment are estimated to be in the range of 4 to 40 tonnes per year for the UN ECE region and up to 260 tonnes for c-octaBDE.
If these emissions are captured and treated they can be reduced by 90% or more. This is mainly determined by the efficiency of the venting system to capture the dust emissions.

The measures taken to reduce emissions of c-pentaBDE, c-octaBDE and SCCP's will also reduce emissions of other pollutants, e.g. heavy metals, other POPs, particulates, odours, etc.
The measures taken will also clean up the workspace atmosphere and improve occupational health.
An example of an installation treating EEE waste can be found on the website of SWICO (ref 5).

6. Costs of emission reduction

The costs of emission reduction can vary and are related to the size of the waste treatment plant and the character of the waste handled and activities employed.
For a small installation the installation costs for a ventilation system attached to a dust filter based on a bag house will be about 50.000 to 100.000 Euro (ref 9). For a large waste treatment plant with several installations and production lines the investment costs can go up to more than a million Euro.
In the assessment of the costs it has to be taken into account that measures to control and abate emissions of POPs from waste handling have more environmental benefits. These are an overall reduction of emissions of Particulate Matter, and depending on the waste treated also reduction of other POPs and of heavy metals. Next to environmental benefits these measures in general also help improve occupational health.

D. Current policies and legislation

Abatement measures for waste treatment facilities of EEE, furniture and car interiors are becoming common nowadays. Main arguments behind these measures are the reduction of emissions of particulate matter and occupational health.

7. Current legislation and policies in the EU and other Parties to the Protocol

In the EU the measures to reduce emissions from waste treatment are regarded as BAT (ref 8).
The legislation for treatment of EEE waste in the EU countries is based on the WEEE (2002/96/EC), the directive for waste treatment. This states that EEE waste has to be collected separately from other wastes and that it has to be treated in installations using BAT to reduce emissions.

Waste from furniture or car interiors has to be treated in installations using BAT to reduce emissions based on the IPPC directive (96/61/EC). This implies that the abatement techniques mentioned in the BAT Reference document are used (ref 8).
In Norway waste containing 0,25 % or more of one of the 5 flame-retardants penta-, octa- and deca-BDE, HBCDD and TBBPA has to be treated as hazardous waste.

E. Conclusion

It is concluded that installations for treatment of waste from EEE, car interiors and furniture can be an important source of emissions of c-pentaBDE, c-octaBDE and SCCPs. Technical measures are available to reduce these emissions by 90% or more and are applied in several EU member states.

8. Proposal for BAT for waste treatment facilities
A new chapter VII could be added to Annex V of the POP Protocol, describing BAT for facilities treating waste from Electronic and Electric Equipment and for treating waste from consumer goods that can contain flame retardants.

VII. Control techniques for the reduction of POPs from treatment of waste from consumer goods

a. waste treatment facilities for Electronic and Electrical Equipment.
b. waste treatment facilities for car interiors including fluff, and facilities for shredding or crushing furniture

BAT is to:
- perform crushing, shredding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment when handling materials that can generate emissions to air containing POPs.
- to prevent or control the emissions of particulate matter BAT is to correctly operate and maintain the abatement equipment.
- reduce air emissions of particulate matter to the levels below 20 mg/Nm3 .

These emission levels can be attained by installing common emission abatement techniques like bag filters or, in some specific cases, scrubbers. The emission reduction efficiency of bag houses is 99% or more. The efficiency of scrubbers for reducing emissions of particulates is in the range of 80% and more.

André Peeters Weem,
InfoMil, The Hague, August 25, 2008

References

1. Report to TF POPs presented by Norway: 'Management options for commercial pBDE', Tallin, May 2006.

2. BSEF, Bromine Science and Environmental Forum: 'An introduction to Brominated Flame Retardants', 19 october 2000, Brussels

3. Morf et al.: ' Brominated flame retardants in waste electrical and electronic equipment, substance flows at a recycling plant. Environ Sci Technol., 2005 nov 15; 39 (22):8691-9.

4. EPA website: www.epa.gov/ecycling, April 24, 2008

5. SWICO website: www.swico.ch/de

6. ICT-Milieu: Onderzoek naar complementaire afvalstromen voor e-waste in Nederland, Witteveen&Bos, Deventer, 14 april 2008.

7.BIPRO: 'Draft Management Option Dossier for commercial octabromodiphenyl ether (c-OctaBDE)', 2 May 2007, European Commission

8. European Commission: Reference Document on Best Available Techniques for the Waste Treatments Industries, August 2006. http://eippcb.jrc.es/

9. InfoMil, fact sheets emission abatement techniques, www.infomil.nl

10. SFT, Bromerte Flammehemmere I Afvallsstrømme, Oslo, May 2008

11. SFT, Årsrapport 2007, Oslo, April 2008.

12. Denier van der Gon et al. Study to the effectiveness of the UNECE POP Protocol and cost of possible additional measures, phase 1; TNO, August 2005, The Netherlands

13. EU Risk Assessment Report, diphenyl etcher pentabromo derivatives, European Chemicals Bureau, EU-Joint Research Centre, 2000.