Swerea IVF
Project Report
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Decabromodiphenyl ether and other flame retardants in plastic waste destined for recycling

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Martin Strååt och Camilla Nilsson

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Our head office is located in Mölndal, and we have local offices in Eskilstuna, Jönköping,

Swerea IVF AB
P O Box 104
SE-431 22 Mölndal
Telephone +46 (0)31-706 60 00
Fax +46 (0)31-27 61 30
www.swerea.se

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Introduction

The Norwegian Environment Agency contracted Swerea IVF AB to collect post-consumer plastics destined for recycling and analyse for levels of total bromine, commercial decabromodiphenyl ether (c-decaBDE), other polybrominated diphenyl ethers (PBDEs) and some other selected brominated flame retardants. The main objective of the study has been to obtain information on the levels of c-decaBDE in plastic waste streams from electric and electronic waste (WEEE) and End-of-Life Vehicles (ELVs). It has also been of interest to see a) how existing sorting and separation methods applied in the industry affects the levels of c-decaBDE in the plastic and b) if the reprocessing of the plastics containing small concentrations of c-decaBDE can cause the formation of POP-BDEs

Background

Commercial decabromodiphenyl ether (c-decaBDE) is an additive flame retardant that has a variety of applications including in plastics, textiles, adhesives, sealants, coatings and inks[1]. It has been under scrutiny for its potential health and environmental impacts for more than a decade. It is detected in all global regions, including in remote areas such as the Arctic where it is transported via air[2]. Emissions of c-decaBDE to the environment occur at all its life cycle stages, but are assumed highest during service-life and in the waste phase. Steps to restrict the use of c-decaBDE have therefore been taken in some countries and regions, as well as by some companies and are now considered globally under the Stockholm Convention[4,2].

C-decaBDE consists predominantly of the congener BDE-209 (≥97%, with low levels of other polybrominated diphenyl ether congeners such as nonabromodiphenyl ether (0.3-3%) and octabromodiphenyl ether (0-0.001%)[3]. In the past, c-decaBDE constituted 75-80% of the world total production of PBDEs and the total global production of c-decaBDE in the period 1970-2005 was between 1.1-1.25 million tonnes. C-decaBDE consumption peaked in the early 2000's, but c-decaBDE is still used worldwide[5].

The main uses of c-decaBDE are in textiles and plastics[4]. Textile applications, which are estimated to around 10% of the total use, include commercial textiles, mainly for public buildings and transport, and textiles for domestic furniture. The main use of c-decaBDE is in plastics, which constitutes up to 90% of all use. A main application of c-decaBDE containing plastics has been in electrical and electronic products where it is found in housings of computers and TVs, wires and cables, pipes and carpets. C-decaBDE containing plastics has also been used in vehicles and airplanes. C-decaBDE may also be found in adhesives, sealants, coatings and inks as well as in wires, cables, tubing, construction materials as well as storage and distribution products such as plastic pallets[4].

. With the exception of means of transportation, its production, use and placing on the market has been banned in Norway since 2008. In the EU, the main constituent of c-decaBDE, BDE-209, is recognized as a persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) substance under the REACH regulation due to its degradation to other PBDEs in the environment, and its use in electrical and electronic equipment is banned by the RoHS regulation. A wider ban covering

[1] Decabromodiphenyl ether (commercial mixture, c-decaBDE). Risk Management Evaluation. Persistent Organic Pollutants Review Committee 2014. UNEP/POPS/POPRC.11/10/Add.2. Available at: http://chm.pops.int/TheConvention/POPsReviewCommittee/POPRCRecommendations/tabid/243/Default.aspx

[2] Decabromodiphenyl ether (commercial mixture, c-decaBDE). Risk Profile. Persistent Organic Pollutants Review Committee 2014. UNEP/POPS/POPRC.10/10/Add.2. Available at: http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC10/POPRC10Documents/tabid/3818/Default.aspx

[3] European Chemicals Agency (2012a). Support Document (Bis(penteabromphenyl) ether [decabromodiphenyl ether](Member State Committee, 29 November 2012)

[4] For further info see UNEP/POPS/POPRC.11/10/Add.1, UNEP/POPS/POPRC.11/INF/6, UNEP/POPS/POPRC.12/5, UNEP/POPS/POPRC.12/INF/9 and UNEP/POPS/POPRC.12/INF/10

its use in preparations and products was published on 10 February 2017, and will enter into force on 2 March 2019. Exemptions are given for aircrafts and spare parts for aircrafts, motor vehicles, agricultural and forestry vehicles as well as some types of machinery.

In 2013, Norway submitted a proposal to list c-decaBDE as a persistent organic pollutant under the Stockholm Convention. Having assessed the persistent organic pollutant characteristics of c-decaBDE the Persistent Organic Review Committee (POPRC) of the Stockholm Convention, in 2014 concluded that "*C-decaBDE with its main constituent BDE-209 is likely, therefore, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted*" and recommended that c-decaBDE with its main constituent BDE-209 be listed in Annex A to the Convention. At the eight meeting of Conference of the Parties to the Stockholm Convention, which took place from 25 to 27 April 2017, parties agreed to list c-decaBDE with several time-limited exemptions for various uses.[5] However, in contrast to the listing of octa- and pentaBDE, no exemptions for recycling was agreed upon for c-decaBDE. Further work relating to the management and handling of c-decaBDE-containing waste, will be undertaken by the Basel Convention.

Materials and Methods

Plastic fractions from different types of sources and stages in the plastic recycling value chain were analysed. To obtain samples for analysis, contacts were made with both online trading sites for recycled plastics and plastics recyclers. The latter were contacted directly via telephone. The suppliers of samples were both small and large plastic recyclers, plastics processors and traders and came from six European countries. Test samples were ordered in the following forms:

1. Shredded material: Size reduced material, often only subjected to a metal separation.[6]
2. Regrind; Shredded material which has been further size reduced in a grinding mill, washed and (in most cases) separated by density or by chemical composition. It could also be clean post-industrial waste which has been size reduced in a grinding mill.[5]
3. Regranulated pellets; Regrind which had also been melt-filtered in an extruder.[5]

The value chain for plastics recycling of WEEE and ELV is described in the figure below and gives an indication of where in the process the sample was taken. An overview of the most commonly used bulk separation techniques is given by K. Freegard et al. in "Develop a process to separate brominated flame retardants from WEEE polymers - final report", 2006 published by the Waste & Resources Action Program and available at www.wrap.co.uk.

[5] SC-8/10: Listing of decabromodiphenyl ether. UNEP-POPS-COP.8.SC-8-10. Available at: http://chm.pops.int/TheConvention/ConferenceoftheParties/ReportsandDecisions/tabid/208/Default.aspx
[6] F. La Mantia, Handbook of Plastics Recycling, Rapra Technology Ltd, 2002

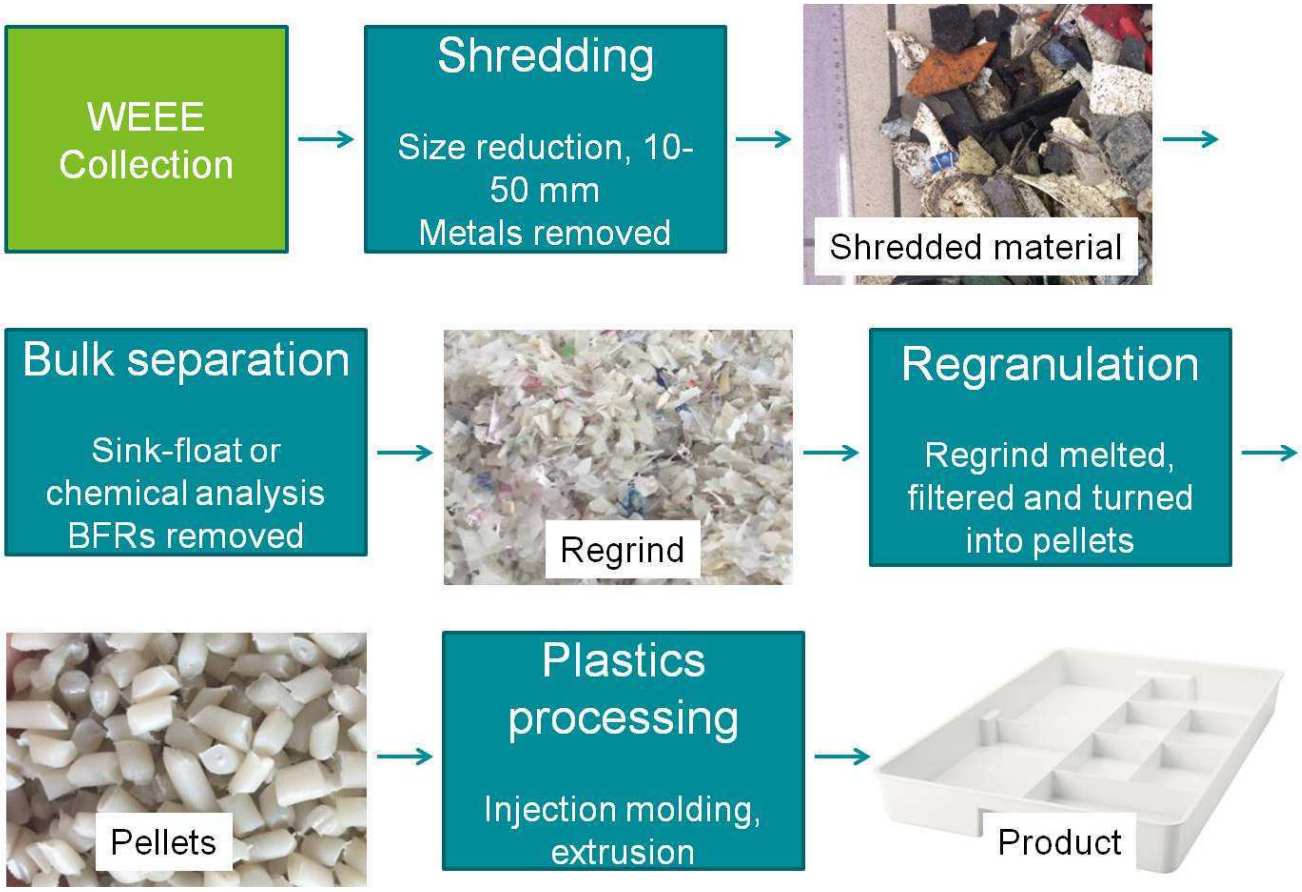

Figure 1. Flow chart of plastics recycling from WEEE and ELV showing the processes used to go from waste to a new product. Shredded material, regrind and pellets are different intermediary products used as raw material for the different processes. The processes require different kinds of expertise where the difference between cold processing and hot (in the molten state) processing is very large.

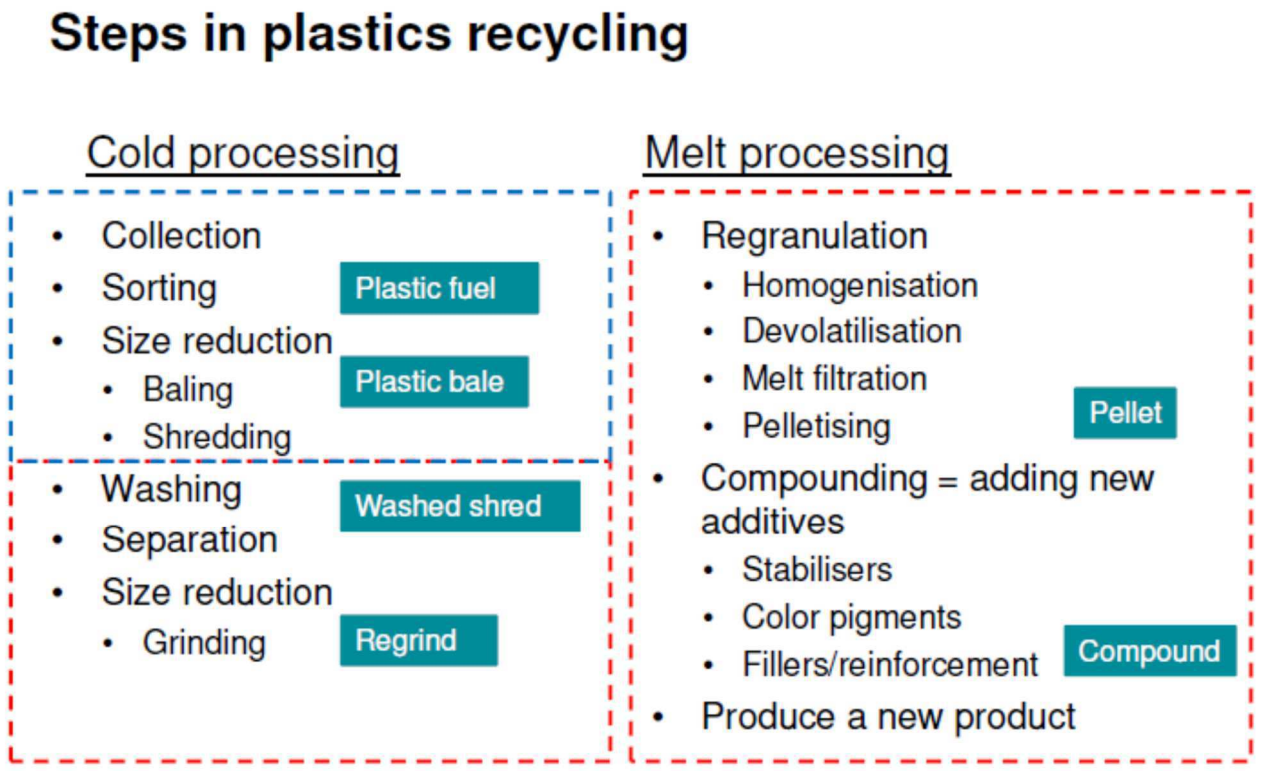

Figure 2. Cold processing methods vs hot processing methods. Recycling companies will most often stay within their own field of expertise with small companies often focusing on just one of the processing steps.

Altogether 50 samples were purchased and tested for total bromine. Out of these 25 samples were analysed by mass spectrometry for BDE-209, other PBDEs and hexabromocyclodecane (HBCD). Ten samples were also analysed for tetrabromobisphenol A (TBBPA) and decabromodiphenylethane (DBDPE). The 25 samples selected for analysis were those with the highest levels of total bromine.

Sample preparation was made prior to testing for total bromine and before quantitative mass spectrometric analysis for selected brominated flame retardants. Sample preparation was done to replicate the actual reuse of the recycled plastic in new products as realistically as possible. Regranulated pellets were injection molded into 4 mm thick tensile test bars. Regrind and shredded material were in some cases melt-filtered before injection molding and in some cases used as they were. In case the sample had less than the required amount for injection molding, compression molding was used to make a 4 mm thick plate. The melt-filtration was performed on a Coperion ZSK 26 twin screw extruder equipped with a screen changer from Gneuss. A 125 µm filter screen was used and the temperature was 220°C. Injection molding was performed on an ES 200/110, manufactured by Engel. The compression molding was made in a heated lab press. The molding temperature was 220°C in both cases. An overview of the samples analysed in this study is provided in Table 1 below.

Injection molding is a very common and widespread process for producing plastic articles for the automotive and electrical and electronics industries. Plastic granules are fed into an injection molding machine having a heated barrel with a screw inside. The heat from the barrel side walls melts the plastic while the screw inside the barrel rotates to feed plastic forwards and homogenizing it, ensuring that all the plastic has reached the processing temperature. When the required amount of plastic has been melted and feed to the nozzle, the molten plastic is injected into a closed steel mold through a small hole. Inside the mold the plastic will cool and solidify. After cooling, the mold opens and the

finished plastic part is ejected. The method has a high degree of automation and is very suitable for high volume production.

Compression molding is a very simple method for producing articles in small series and it generates low amounts of waste. Plastic material is placed in an open, heated mold. The mold is closed and the heat from the mold walls melts the plastic. The mold is then cooled making the plastic inside the mold also cool and solidify. When the plastic has solidified enough, the mold is opened again. Note that there is no homogenization taking place when compression molding.
Melt filtration is a process to remove solid contaminants from a plastic material. Plastic material, containing solid contaminants, is fed through a hopper into an extruder having a heated barrel with a screw inside. The heat from the barrel side walls melts the plastic while the screw inside the barrel rotates to feed plastic forwards and homogenizing it, ensuring that all the plastic has reached the processing temperature. When the material reaches the end of the screw, the pressure pushes the melt through a series of woven metal nets (the filter). The pore size of the filter depends on the application with a typical range between 80-250 µm. When recycling of post-consumer plastics from electronics or ELV waste it is common to use filters around 150 µm in size. The filter will stop the solid contaminants that are larger than the spaces between wires in the metal net. After the filter, the molten plastic is pushed through a die plate with small holes in, from which it exits as protruding strands. A rotating knife cuts the molten plastic into 3-5 mm small pellets. These pellets are often called regranulates to emphasize that the raw material comes from recycled plastics and the entire process is called *regranulation*. Melt filtration is a necessary step to produce useable materials from almost all recycled post-consumer waste since it both homogenizes the material to a high degree and removes solid contaminants that can cause large problems in the following processes, such as injection molding. For post-industrial waste, where there is little variation in the recycled plastic and close to no solid contaminants, it is sometimes not necessary to use melt filtration and regrind from these sources may be used directly. The screw and barrel in a melt filtration extruder is longer than in an injection molding machine to give a better homogenization of the plastic.
Grinding is a process to size-reduce plastic parts into small 4 - 10 mm pieces which can be fed through a hopper into an injection molding machine or an extruder. Plastic parts are cut by rotating knifes with a hole plate underneath. When the plastic pieces are smaller than the diameter of the holes, they fall through the hole plate and are collected in a container. The product is called a *regrind*. Note that the grinding creates a certain degree of mixing in case different plastic articles are grinded at the same time. Also note that it is a cold process so the plastic is never melted.

Screening for bromine (Br) was performed with an X-ray fluorescence (XRF) spectroscopy ED-XRF, Niton XL3t (Holger Andreasen AB) on the injection moulded test bars.

Quantitative determination of selected brominated flame retardants were performed using Gas Chromatograph-Mass Spectrometry (GC-MS), GC model 7890A, MS model 5975C, manufactured by Agilent. Prior to analysis and injection into the GC-MS samples were extracted with toluene, TBBPA was in addition derivatized with acetic anhydride. The measurements were performed by TÜV Rheinland, see Appendix 0003210193/30 AZ 260168 and 0003239809/30 AZ 290127

List of abbreviations

PP = Polypropylene, a common thermoplastic often used in automotive and electrical equipment in many injection molded parts. Rarely containing brominated flame retardants.
PE = Polyethylene, a common thermoplastic often used in extruded profiles, plastic film, fluid containers and hoses. Very rarely containing flame retardants.
HIPS = High Impact Polystyrene, a thermoplastic often used in electrical equipment in many injection molded parts. The most common application is extruded sheets for thermoforming for example cabinet liners in cooling appliances (fridges and coolers). In many applications it may contain high levels of brominated flame retardants.
ABS = Acrylonitrile-Butadiene-Styrene, a thermoplastic often used in automotive and electrical equipment in injection molded parts when temperature resistance, surface finish and impact resistance is required.
PC = Polycarbonate, an expensive thermoplastic often used as a blend with ABS to increase both impact and temperature resistance.

Table 1. Overview of XRF analysed samples and sample preparation prior to analysis

Sample ID.	Company	Country	Plastic type[1]	Waste stream, product/ waste category	Info on treatment in facility	Categroy	Sample preparation
1	NOR1	Norway	PP/PE	WEEE, Small domestic appliances	Density separation	Regrind	Injection molding
2	NOR1	Norway	PP/PE	WEEE, Small domestic appliances	Density separation	Regrind	Melt filtration + Injection molding
3	NOR1	Norway	HIPS	WEEE, Fridges	Density separation	Regrind	Injection molding
4	NOR1	Norway	HIPS	WEEE, Fridges	Density separation	Regrind	Melt filtration + Injection molding
5	NOR1	Norway	ABS	WEEE, Fridges	Density separation	Regrind	Injection molding
6	NOR1	Norway	ABS	WEEE, Fridges	Density separation	Regrind	Melt filtration + Injection molding
7	GER1	Germany	PS	WEEE, Small domestic appliances	No information given	Regrind	Injection molding
8	GER1	Germany	PS	WEEE, Small domestic appliances	No information given	Regrind	Melt filtration + Injection molding
9	NOR1	Norway	PP/PE	WEEE, Fridges	Density separation	Regrind	Injection molding
10	NOR1	Norway	PP/PE	WEEE, Fridges	Density separation	Regrind	Melt filtration + Injection molding
11	SPA1	Spain	ABS	WEEE; TV cases	No information given	Regrind	Compression molding
12	SPA1	Spain	PS/ABS	WEEE; Mix of post consumer EEE	No information given	Regrind	Compression molding
13	NOR1	Norway	PS	WEEE; Small domestic appliances	Density separation	Regrind	Melt filtration + Injection Molding
14	GER2	Germany	PC/ABS	Production waste, electronic TV cases	Manual sorting on site.	Regrind	Melt filtration + Injection molding
15	NOR1	Norway	PP/PE	ELV hard plastic shred	Density	Regrind	Injection molding

16	SWE1	Sweden	PP/PE	Production waste automotive.	Manual sorting on site.	Regrind	Melt filtration + Injection molding
17	UK1	UK	PS	WEEE, Fridges	No information given	Shredded	Grinding, melt filtration, injection molding
18	FRA1	France	PP/PE	ELV + household	Density	Regranulate	Injection molding
19	FRA1	France	PP/PE	ELV	Density	Regrind	Injection molding
20	FRA1	France	PS/ABS	ELV	Density	Regrind	Injection molding
21	FRA1	France	PS/ABS	WEEE, Small domestic appliances	Density	Regrind	Injection molding
22	FRA1	France	PS	WEEE, Small domestic appliances	Density	Regranulate	Injection molding
23	FRA1	France	PS	WEEE, Small domestic appliances	Density	Regranulate	Injection molding
24	FRA1	France	PS	WEEE, Small domestic appliances	Density	Regranulate	Injection molding
25	FRA1	France	ABS	WEEE, Small domestic appliances	Density	Regrind	Injection molding
26	FRA1	France	ABS	WEEE, Small domestic appliances	Density	Regranulate	Injection molding
27	FRA1	France	PS/ABS	WEEE, Small domestic appliances	Density	Regrind	Injection molding
28	FRA1	France	PS/ABS	WEEE, Small domestic appliances	Density	Regrind	Injection molding
29	SWE2	Sweden	PS/ABS	WEEE, Small domestic appliances	Density	Shredded	Grinding, Injection molding
30	NOR1	Norway	ABS	WEEE, Small domestic appliances	Density	Regrind	Melt filtration, injection molding
31	UK2	United Kingdom	PP	ELV	Density	Pellets	Injection molding
32	UK2	United Kingdom	PP	ELV	Density	Pellets	Injection molding
33	UK2	United Kingdom	PP	ELV	Density	Pellets	Injection molding
34	UK2	United Kingdom	PP	ELV	Density	Pellets	Injection molding
35	UK2	United Kingdom	PP	ELV	Density	Regrind	Injection molding
36	UK2	United Kingdo	PP	ELV	Density	Regrind	Injection molding

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37	UK2	United Kingdom	PP	ELV	Density	Regrind	Injection molding
38	UK2	United Kingdom	ABS	ELV	Density	Regrind	Injection molding
39	AU1	Austria	ABS	ELV + WEEE (small domestic appliances)	Density + electrostatic	Pellets	Injection molding
40	AU1	Austria	PP	ELV + WEEE (small domestic appliances)	Density + electrostatic	Pellets	Injection molding
41	AU1	Austria	PS	ELV + WEEE (small domestic appliances)	Density + electrostatic	Pellets	Injection molding
42	SK1	Slovakia	PS	WEEE (fridges)	Density + electrostatic	Pellets	Injection molding
43	SK1	Slovakia	ABS	WEEE (fridges)	Density + electrostatic	Pellets	Injection molding
44	UK3	United Kingdom	PP	WEEE (small domestic appliances)	Density	Pellets	Injection molding
45	UK3	United Kingdom	ABS	WEEE (small domestic appliances)	Density	Pellets	Injection molding
46	UK3	United Kingdom	PS	WEEE (small domestic appliances)	Density	Pellets	Injection molding
47	SWE4	Sweden	ABS	WEEE (TV:s and monitors)	handheld XRF	Regrind	Injection molding
48	SWE4	Sweden	PS	WEEE (TV:s and monitors)	handheld XRF	Regrind	Injection molding
49	SWE5	Sweden	PP	ELV (battery cases)	Dry separation	Shredded	size reduction + Injection molding
REF	SWE4	Sweden	PP/PS/ABS	WEEE (TV:s and monitors)	No separation	Shredded	size reduction + melt mixing + compression molding

Results

Decabromodiphenylether (Deca-BDE / BDE-209)

Out of the 50 samples collected and analysed by XRF, 21 had Br levels above 500 ppm. 25 samples were selected for analysed by mass spectrometry. GC-MS analysis of these samples showed that 22 samples contained BDE-209. None of the samples had BDE-209 levels above 1000 ppm. The highest concentration measured was 900 ppm BDE-209, which was found in the unseparated reference sample. This was a sample of PS/ABS material and came from TV-cases products. For the commercial materials that had gone through a separation process, the highest measured concentration of BDE-209 was 280 ppm and came from small domestic appliances.

Other POP-BDEs

Of 24 commercial materials analysed, only 5 contained measurable amounts of POP-BDEs with the highest measured concentration being 16 ppm. The unseparated reference sample contained a slightly higher concentration of 52 ppm.

Decabromodiphenylethane (DBDPE)

Of 9 commercial materials analysed, all contained decabromodiphenylethane with the highest concentration measured being 400 ppm. The unseparated reference sample contained more than 3000 ppm.

Tetrabromobisphenol A (TBBPA)

Of 9 commercial materials analysed, 8 contained small amounts of TBBPA where the highest concentration measured was 130 ppm. The unseparated reference sample contained a significantly higher amount of TBBPA, 1100 ppm.

Hexabromocyclododecane (HBCDD)

Of 24 commercial materials analyzed only 6 samples contained levels above 10 ppm, highest level measured was 47 ppm.

The results of the measurements are summarized in Table 2 below. All results relate only to the material tested.

Table 2. Overview of results[1] (levels in ppm or mg/kg).

Sample ID.	Company	Country	Plastic type[1]	Waste stream, product/ waste category	Br (ppm)	BDE-209	∑POP-BDEs[2]	∑PBDE[3]	TBBPA[4]	DBDPE[5]	HBCDD[6]
1	NOR1	Norway	PP/PE	WEEE, Small domestic appliances	781	50	<5	50	-	-	<10
2	NOR1	Norway	PP/PE	WEEE, Small domestic appliances	795	76	<5	76	-	-	<10
3	NOR1	Norway	PS	WEEE, Fridges	147	-	-	-	-	-	-
4	NOR1	Norway	PS	WEEE, Fridges	101	-	-	-	-	-	-
5	NOR1	Norway	ABS	WEEE, Fridges	606	-	-	-	-	-	-
6	NOR1	Norway	ABS	WEEE, Fridges	601	170	<5	177	-	-	<10
7	GER1	Germany	PS	WEEE, Small domestic appliances	18 700	610	5,8	624	-	-	<10
8	GER1	Germany	PS	WEEE, Small domestic appliances	19 200	610	6	625	-	-	<10
9	NOR1	Norway	PP/PE	WEEE, Fridges	224	-	-	-	-	-	-
10	NOR1	Norway	PP/PE	WEEE, Fridges	194	-	-	-	-	-	-
11	SPA1	Spain	ABS	WEEE; TV cases	415	44	7,7	52	-	-	<10
12	SPA1	Spain	PS/ABS	WEEE; mix of post consumer EEE	232	-	-	-	-	-	-
13	NOR1	Norway	PS	small domestic appliances	165	-	-	-	-	-	-
14	GER2	Germany	PC/ABS	Electronic, post-industrial, TV cases	nd	-	-	-	-	-	-
15	NOR1	Norway	PP/PE	ELV	120	-	-	-	-	-	-
16	SWE1	Sweden	PP/PE	Production waste automotive.	nd	-	-	-	-	-	-
17	UK1	United kingdom	PS	WEEE, Fridges	549	<5	<5	<5	-	-	<10
18	FRA1	France	PP/PE	ELV + household	66	-	-	-	-	-	-
19	FRA1	France	PP/PE	ELV	180	-	-	-	-	-	-

20	FRA1	France	PS/ABS	ELV	470	140	<5	140	-	-	<10
21	FRA1	France	PS/ABS	WEEE, Small domestic appliances	510	25	<5	25	-	-	<10
22	FRA1	France	PS	WEEE, Small domestic appliances	550	100	<5	100	-	-	<10
23	FRA1	France	PS	WEEE, Small domestic appliances	880	99	<5	99	-	-	41
24	FRA1	France	PS	WEEE, Small domestic appliances	47	-	-	-	-	-	-
25	FRA1	France	ABS	WEEE, Small domestic appliances	397	-	-	-	-	-	-
26	FRA1	France	ABS	WEEE, Small domestic appliances	195	-	-	-	-	-	-
27	FRA1	France	PS/ABS	WEEE, Small domestic appliances	813	52	<5	52	-	-	<10
28	FRA1	France	PS/ABS	WEEE, Small domestic appliances	1189	120	<5	120	-	-	36
29	SWE2	Sweden	PS/ABS	WEEE, Small domestic appliances	1150	280	5,6	291	-	-	<10
30	NOR1	Norway	ABS	WEEE, Small domestic appliances	1224	150	16	176	-	-	<10
31	UK2	United Kingdom	PP	ELV	110	-	-	-	-	-	-
32	UK2	United Kingdom	PP	ELV	57	-	-	-	-	-	-
33	UK2	United Kingdom	PP	ELV	61	-	-	-	-	-	-
34	UK2	United Kingdom	PP	ELV	213	-	-	-	-	-	-
35	UK2	United Kingdom	PP	ELV	274	<5	<5	<5	<5	5.9	<5
36	UK2	United Kingdom	PP	ELV	156	-	-	-	-	-	-
37	UK2	United Kingdom	PP	ELV	39	-	-	-	-	-	-
38	UK2	United Kingdom	ABS	ELV	286	5,1	<5	5,1	15	13.5	<5
39	AU1	Austria	ABS	ELV + WEEE (small domestic appliances)	162	-	-	-	-	-	-
40	AU1	Austria	PP	ELV + WEEE (small domestic appliances)	613	85	<5	85	20	140	11
41	AU1	Austria	PS	ELV + WEEE (small domestic appliances)	970	94	<5	94	26	400	47
42	SK1	Slovakia	PS	WEEE (fridges)	119	-	-	-	-	-	-
43	SK1	Slovakia	ABS	WEEE (fridges)	52	-	-	-	-	-	-
44	UK3	United Kingdom	PP	WEEE (small domestic appliances)	682	130	<5	130	27	190	<5
45	UK3	United Kingdom	ABS	WEEE (small domestic appliances)	961	<5	<5	<5	45	160	<5
46	UK3	United Kingdom	PS	WEEE (small domestic	851	160	<5	160	26	220	6.1

				appliances)							
47	SWE4	Sweden	ABS	WEEE (TV:s and monitors)	280	20	<5	20	130	6.9	<5
48	SWE4	Sweden	PS	WEEE (TV:s and monitors)	646	43	<5	43	60	30	15
49	SWE5	Sweden	PP	ELV (battery cases)	98	-	-	-	-	-	-
REF	SWE4	Sweden	PP/PS/ ABS	WEEE (TV:s and monitors)	2175	900	52	952	1100	>3000	<5

[1]nd= not detected/ levels were below the limit of detection. For information on limits of detection se complete analysis report in Appendix.
[2]∑POP-BDEs; PBDEs currently listed in Annex A to the Stockholm Convention including tetra-, penta-, hexa- and heptaBDE.
[3]∑PBDE; sum of mono-, di-, tri-, tetra-,penta-, hexa-, hepta-, octa-, nona- and decaBDE.
[4]Tetrabromobisphenol A
[5] Decabromodiphenylethane
[6] Hexabromocyclododecane

Comments

Please note that the reference sample is not a commercial material available for sale. It was specifically ordered from a recycler to be sampled **before** entering the separation process in order to get a reference material for untreated materials.

It seems likely that samples 7 and 8 have not gone through any kind of separation process to reduce Br-content. The supplier of this material also gave no description of any such treatment process.

In order to study the influence of regranulation, including melt filtration, on the material composition, 5 regrind materials were tested before and after the regranulation. The results can be seen in samples 1-10. It is clear that the regranulation process does not lead to the formation of POP-BDEs from other brominated flame retardants. If this was the case, we would see a decrease in the concentration of BDE-209 and an increase in the concentration of POP-BDEs. The only effect noted from regranulation was a reduced variation in the measured bromine content between measurements of the same sample batch.

Discussion

Most of the recyclers in this study use the same techniques. They start with shredding and do the sorting on shredded materials with XRF and density separation. The reject percentage naturally differs between waste streams, operators and technologies used but some general estimates can be made based on information from waste separation operators:

* Separated plastic from fridges (WEEE): ~ 20% rejected
* Separated plastic from small domestic appliances (WEEE): ~30% rejected
* Separated plastics from automotive shredders (ELV): ~50% rejected

Some samples also had high Br-levels without having high PBDE-levels indicating the presence of other brominated flame retardants. Even when including the decabromodiphenylethane, TBBPA and HBCD, the total sum of brominated flame retardants was lower than the Br concentration measured with XRF. The reason for this discrepancy is most likely the presence of other brominated substances not analysed in this study. There are also inherent differences in the measurement methods of GC-MS vs XRF where one measure the concentration of specific brominated compounds and the other the concentration of bromine atoms, respectively.

Based on our findings it is very difficult to draw any meaningful relationship between the Br-concentration measured using XRF and the concentration of restricted brominated flame retardants measured using GC-MS. The only thing that can be said with certainty is that the concentration of restricted flame retardants measured is lower than 25% of the Br-concentration measured using XRF.

The large differences between samples, in the concentrations of restricted flame retardants measured by GC-MS, could be easier understood by taking into account the facts that:

1) The products ending up in the different waste streams are of different age. Some products are used longer than others and therefore there will be a larger number of old products in these waste streams.
2) There are differences in the waste streams coming from different countries.
3) There has been an ongoing substitution of restricted flame retardants over time.

The combination of these three facts means that some waste streams will contain a larger amount of older products with restricted flame retardants than others. As a consequence, the total concentration of the restricted flame retardants included in this study should gradually decrease at a different rate for each waste stream and country. Each study on this topic should therefore be viewed as a snap shot of the current situation and the concentrations of restricted chemicals in the waste streams should therefore be monitored regularly to give an overview of the current state of pollutants in the waste.

Concentrations of POP-BDEs were generally very low, with an average level below the detection limit of 5 ppm. The highest measured concentration in the sorted fractions was 16 ppm while the unsorted reference sample contained 52 ppm. Since the reference sample comes from a waste stream which is a mix of all products put on the market for the last decade, it shows how effective the substitution of restricted brominated flame retardants has been carried out by the industry.
The total sum of PBDEs (including decaBDE) + HBCDD and TBBPA, had an average level of 116 ppm. The highest measured concentration in the sorted fractions was 291 ppm compared with 2052 ppm in the unsorted reference sample of which a large part was TBBPA. This shows how effective the methods used for sorting out material with brominated flame retardants is, and especially for TBBPA.

Concerns have been expressed that the regranulation, which includes reprocessing a material at a high temperature, could debrominate deca-BDE to other POP-BDEs. However the findings of this report clearly points to that degree of debromination of decaBDE is minimal at the temperature used in this study.

Conclusions

Although a limited number of samples were analyzed in this study, the following conclusions could be drawn:

- Post-consumer plastics that have undergone sorting- and separation in the state of the art recycling facilities investigated in this study were found to contain no or low levels of c-decaBDE (in this study typically < 1000 ppm)
- Levels of other PBDEs were typically below detection, however low levels of other c-decaBDE components such as octa- and nonaBDE were detected in a few samples.
- Low levels of HBCD was detected along with BDE-209 in 5 out of 25 samples analyzed by GC-MS. These samples were from WEEE fractions containing small domestic appliances and TV cases.
- TBBPA, although in low levels, was detected in 9 out of 10 samples analysed. The reference sample contained a relatively high level (1100 ppm).
- DBDPE was found in all commercial samples analysed where the highest level measured was 400 ppm. The unsorted reference sample contained very high levels (>3000 ppm).
- Some samples were found to contain high levels of total bromine. The bromine in those samples likely come from the use of other brominated flame retardants that are still available on the market.

Appendix

TÜV Rheinland report 0003210193/30 AZ 260168

TÜV Rheinland report 0003239809/30 AZ 290127

TÜV Rheinland LGA Products GmbH · 51101 Cologne

Swerea IVF AB
Camilla Nilsson
Po Box 104
431 22 Mölndal
SWEDEN

Contact Petra Van Dyck
E-Mail Petra.Van.Dyck@de.tuv.com
Phone +49 221/806-2129
Fax +49 221/806-2882
Cologne, 22.02.2017

Report No. 0003210193/30 AZ 260168

Test item:	15 plastic samples Detailed list see next page
Condition at delivery:	No claim
Date of delivery:	16.02.2017
Place of testing:	Cologne
Test period:	17.02.2017 to 22.02.2017
Test scope:	Parameters selected by customer

Cologne, 22.02.2017

Dipl.-Ing. Gunther Bier
(Expert)

P. Van Dyck
Petra Van Dyck
(Expert)

Report No.: 0003210193/30 AZ 260168
Date: 22.02.2017

Test item: 15 plastic samples

Detailed list:

1) Swerea PP/PE
2) Swerea PP/PE
6) Swerea ABS
7) Swerea PS
8) Swerea PS
11) Swerea ABS
17) Swerea PS
20) Swerea PS/ABS
21) Swerea PS/ABS
22) Swerea PS
23) Swerea ABS
27) Swerea PS
28) Swerea PS
29) Swerea PS
30) Swerea ABS

Report No.: 0003210193/30 AZ 260168
Date: 22.02.2017

1. Results

Flame retardants, brominated biphenyls and biphenyl ether

Sample No.	260168-016	260168-017	260168-018
Sample composition	**Art. 1**	**Art. 2**	**Art. 3**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	6,8
Decabromodiphenyl ether	50	76	170

Sample No.	260168-019	260168-020	260168-021
Sample composition	**Art. 4**	**Art. 5**	**Art. 6**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	5,8	6	7,7
Nonabromodiphenyl ethers	8,1	8,6	<5
Decabromodiphenyl ether	610	610	44

Report No.: 0003210193/30 AZ 260168
Date: 22.02.2017

Sample No.	260168-022	260168-023	260168-024
Sample composition	**Art. 7**	**Art. 8**	**Art. 9**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	<5
Decabromodiphenyl ether	<5	140	25

Sample No.	260168-025	260168-026	260168-027
Sample composition	**Art. 10**	**Art. 11**	**Art. 12**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	<5
Decabromodiphenyl ether	100	99	52

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Date: 22.02.2017

Sample No.	260168-028	260168-029	260168-030
Sample composition	**Art. 13**	**Art. 14**	**Art. 15**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	5,6	16
Nonabromodiphenyl ethers	<5	5,4	9,9
Decabromodiphenyl ether	120	280	150

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Date: 22.02.2017

Sample No.	260168-001	260168-002	260168-003
Sample composition	Art. 1	Art. 2	Art. 3
Unit	mg/kg	mg/kg	mg/kg
Hexabromo-cyclododecane, HBCDD	<10	<10	<10

Sample No.	260168-004	260168-005	260168-006
Sample composition	Art. 4	Art. 5	Art. 6
Unit	mg/kg	mg/kg	mg/kg
Hexabromo-cyclododecane, HBCDD	<10	<10	<10

Sample No.	260168-007	260168-008	260168-009
Sample composition	Art. 7	Art. 8	Art. 9
Unit	mg/kg	mg/kg	mg/kg
Hexabromo-cyclododecane, HBCDD	<10	<10	<10

Sample No.	260168-010	260168-011	260168-012
Sample composition	Art. 10	Art. 11	Art. 12
Unit	mg/kg	mg/kg	mg/kg
Hexabromo-cyclododecane, HBCDD	<10	41	<10

Sample No.	260168-013	260168-014	260168-015
Sample composition	Art. 13	Art. 14	Art. 15
Unit	mg/kg	mg/kg	mg/kg
Hexabromo-cyclododecane, HBCDD	36	<10	<10

Limit for the content of tetrabromodiphenylether, pentabromodiphenylether, hexabromodiphenylether and heptabromodiphenylether in preparations and parts of articles acc. to regulation (EC) no. 850/2004: <= 10 mg/kg (0.001 % w/w) each.
Limit for octabromdiphenylether in preparations and parts of articles acc. to regulation 1907/2006/EC Annex XVII < 0.1 % (w/w).
Limit for HBCDD according to Annex I of Regulation (EC) No 850/2004 (issue 01.03.2016): 100 mg/kg (0,01 % by weight).

Report No.: 0003210193/30 AZ 260168
Date: 22.02.2017

2. Summary of methods

Flame retardants, brominated biphenyls and biphenyl ether		

Method description: In-house method - Determination of brominated biphenyls and biphenyl ether after extraction with solvent, quantification by GC-MS
Notes: Quantification according to: Method proposal Federal Institute for Material Research and Testing, Lab IV.22 Emission from materials, Berlin, Germany.

----End of report----

TÜV Rheinland LGA Products GmbH · 51101 Cologne

Swerea IVF AB
Camilla Nilsson
Po Box 104
431 22 Mölndal
SWEDEN

Contact Petra Van Dyck
E-Mail Petra.Van.Dyck@de.tuv.com
Phone +49 221/806-2129
Fax +49 221/806-2882
Cologne, 12.12.2017

Report No. 0003239809/30 AZ 290127

Test item:	10 Plastic Samples
Identification:	35) Swerea PP 38) Swerea ABS 40) Swerea PP 41) Swerea PS 44) Swerea PP 45) Swerea ABS 46) Swerea PS 47) Swerea ABS 48) Swerea PS 50) Swerea PS/ABS
Condition at delivery:	No claim
Date of delivery:	01.12.2017
Place of testing:	Cologne
Test period:	07.12.2017 to 12.12.2017
Test scope:	Parameters selected by customer

Cologne, 12.12.2017

X P. Van Dyck

Sachverständige(r)/Expert
Signiert von: Petra Van Dyck

X S Schöneich

Sachverständige(r)/Expert
Signiert von: Sandra Schoeneich

Report No.: 0003239809/30 AZ 290127
Date: 12.12.2017

1. Results

Flame retardants

Sample No.	**290127-014**	**290127-015**	**290127-016**
Sample composition	**Art. 1 35) Swerea PP**	**Art. 2 38) Swerea ABS**	**Art. 3 40) Swerea PP**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	<5
Decabromodiphenyl ether	<5	5.1	85
Hexabromo-cyclododecane, HBCDD	<5	<5	11
Decabromodiphenylethane	5,9	13,3	140

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Sample No.	**290127-017**	**290127-018**	**290127-019**
Sample composition	**Art. 4 41) Swerea PS**	**Art. 5 44) Swerea PP**	**Art. 6 45) Swerea ABS**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	<5
Decabromodiphenyl ether	94	130	<5
Hexabromo-cyclododecane, HBCDD	47	<5	<5
Decabromodiphenylethane	400	190	160

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Date: 12.12.2017

Sample No.	**290127-020**	**290127-021**	**290127-022**
Sample composition	**Art. 7 46) Swerea PS**	**Art. 8 47) Swerea ABS**	**Art. 9 48) Swerea PS**
Unit	mg/kg	mg/kg	mg/kg
Flame retardant substances			
Monobromobiphenyls	<5	<5	<5
Dibromobiphenyls	<5	<5	<5
Tribromobiphenyls	<5	<5	<5
Tetrabromobiphenyls	<5	<5	<5
Pentabromobiphenyls	<5	<5	<5
Hexabromobiphenyls	<5	<5	<5
Heptabromobiphenyls	<5	<5	<5
Octabromobiphenyls	<5	<5	<5
Nonabromobiphenyls	<5	<5	<5
Decabromobiphenyls	<5	<5	<5
Monobromodiphenyl ethers	<5	<5	<5
Dibromodiphenyl ethers	<5	<5	<5
Tribromodiphenyl ethers	<5	<5	<5
Tetrabromodiphenyl ethers	<5	<5	<5
Pentabromodiphenyl ethers	<5	<5	<5
Hexabromodiphenyl ethers	<5	<5	<5
Heptabromodiphenyl ethers	<5	<5	<5
Octabromodiphenyl ethers	<5	<5	<5
Nonabromodiphenyl ethers	<5	<5	<5
Decabromodiphenyl ether	160	20	43
Hexabromo-cyclododecane, HBCDD	6.1	<5	15
Decabromodiphenylethane	220	6,9	30

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Date: 12.12.2017

Sample No.	**290127-023**		
Sample composition	**Art. 10 50) Swerea PS/ABS**		
Unit	mg/kg		
Flame retardant substances			
Monobromobiphenyls	<5		
Dibromobiphenyls	<5		
Tribromobiphenyls	<5		
Tetrabromobiphenyls	<5		
Pentabromobiphenyls	<5		
Hexabromobiphenyls	<5		
Heptabromobiphenyls	<5		
Octabromobiphenyls	<5		
Nonabromobiphenyls	<5		
Decabromobiphenyls	<5		
Monobromodiphenyl ethers	<5		
Dibromodiphenyl ethers	<5		
Tribromodiphenyl ethers	<5		
Tetrabromodiphenyl ethers	<5		
Pentabromodiphenyl ethers	<5		
Hexabromodiphenyl ethers	<5		
Heptabromodiphenyl ethers	<5		
Octabromodiphenyl ethers	36		
Nonabromodiphenyl ethers	16		
Decabromodiphenyl ether	900		
Hexabromo-cyclododecane, HBCDD	<5		
Decabromodiphenylethane	>3000		

Requirement according to Washington State Law Chapter RCW 70.76: Prohibition of brominated diphenyl ethers (PBDEs).
Requirement according to Oregon Revised Statutes (ORS) Vol. 10 Chapter 453: Prohibition of Penta, Octa, DecaBDE.
Requirement for decabromodiphenylether (DecaBDE), hexabromocyclododecane (HBCDD), tetrabromobisphenol A (TBBPA), tris(2-chloroethyl) phosphate (TCEP) and tris(1,3-dichloro-2-propyl)phosphate (TCPP) according to the "Children's Safe Products Act" (CSPA) Washington State Law Chapter RCW 70.240: <= 1000 mg/kg; Limit for mandatory reporting as Chemicals of High Concern to Children (CHCC) according to Chapter 173-334 WAC: each > 100 mg/kg and according to Oregon's Toxic Free Kids Act (Senate Bill 478; Chapter 786, 2015 Laws) as well as according to Vermont Act 188 (S.239; 18 V.S.A. chapter 38A): each >= 100 mg/kg.
Limit for mandatory reporting of decabromodiphenyl ether (deca BDE) and/or hexabromocylododecane (HBCD) as "Priority Chemicals" in children's products according to Maine law 38 M.R.S. § 1695, Chapter 889 > 0.01 % each
Requirement for isopropylated triphenyl phosphate (IPTPP), triphenyl phosphate (TPP), tris-(2-chloroisopropyl)phosphate (TCPP), 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB), bis(2-ethylhexyl) tetrabromophthalate (TBPH) and 2,2-bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate) (V6): future/planned reporting duty as Chemicals of High Concern to Children (CHCC) according to Chapter 173-334 WAC: each > 100 mg/kg
In California there are various settlements concerning the use of the following flame retardants in children's products: pentabromodiphenylether (PentaBDE), octabromodiphenylether (OctaBDE), decabromodiphenylether (DecaBDE), tris(2,3-dibromopropyl)phosphate (TDBPP, TRIS), triphenylphosphate (TPP), bis(2-ethylhexyl) tetrabromophthalate (TBPH), 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB), 2,2-bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate) (V6), tris(2-chloroethyl)phosphate (TCEP), tris(1-chloro-2-propyl)phosphate (TCPP) and tris(1,3-dichloro-2-propyl)phosphate (TDCPP).

Report No.: 0003239809/30 AZ 290127
Date: 12.12.2017

Flame retardants, Tetrabromobisphenol A

Sample No.	**290127-014**	**290127-015**	**290127-016**
Sample composition	**Art. 1 35) Swerea PP**	**Art. 2 38) Swerea ABS**	**Art. 3 40) Swerea PP**
Unit	mg/kg	mg/kg	mg/kg
Tetrabromobisphenol A	<5	15	20

Sample No.	**290127-017**	**290127-018**	**290127-019**
Sample composition	**Art. 4 41) Swerea PS**	**Art. 5 44) Swerea PP**	**Art. 6 45) Swerea ABS**
Unit	mg/kg	mg/kg	mg/kg
Tetrabromobisphenol A	26	27	45

Sample No.	**290127-020**	**290127-021**	**290127-022**
Sample composition	**Art. 7 46) Swerea PS**	**Art. 8 47) Swerea ABS**	**Art. 9 48) Swerea PS**
Unit	mg/kg	mg/kg	mg/kg
Tetrabromobisphenol A	26	130	60

Sample No.	**290127-023**		
Sample composition	**Art. 10 50) Swerea PS/ABS**		
Unit	mg/kg		
Tetrabromobisphenol A	1100		

Report No.: 0003239809/30 AZ 290127
Date: 12.12.2017

2. Summary of methods

Flame retardants		

Method description: In-house method - Determination of selected flame retardants after extraction with toluene, quantification by GC-MS

Flame retardants, Tetrabromobisphenol A		

Method description: In-house method - Determination of tetrabromobisphenol A after extraction with toluene, derivatisation with acetic anhydride, quantification by GC-MS

----End of report----