BROMINATED FLAME RETARDANTS IN PLASTIC PRODUCTS FROM CHINA, INDONESIA, AND RUSSIA

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BROMINATED FLAME RETARDANTS IN PLASTIC PRODUCTS FROM CHINA, INDONESIA, AND RUSSIA

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IPEN is a network of non-governmental organizations working in more than 120 countries to reduce and eliminate the harm to human health and the environment from toxic chemicals.

www.ipen.org

Arnika is a Czech non-governmental organisation established in 2001. Its mission is to protect nature and a healthy environment for future generations both at home and abroad.

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BACKGROUND

Brominated flame retardants (BFRs) are man-made chemicals that are regularly added to consumer products to reduce fire-related injury and damage. The massive production and use of BFRs was initiated as a response to frequent fires started by cigarettes in the 1970s. This solution focused on chemical fire retardants, rather than measures to increase fire safety of cigarettes[2, 3] and led to the development of related fire safety standards focused on chemical fire retardance[4]. Since the 1970s, brominated flame retardants have been used in consumer products such as electronics, furniture and car upholstery, matrasses, household textiles and building insulation[5-7].

THE PROBLEM WITH BFRs

BFRs include several different types of chemicals, such as polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), and tetrabromobisphenol A (TBBPA), each with their set of hazardous properties. They have typically been used in acrylonitrile butadiene (ABS) plastics, polyurethane (PU) foams and polystyrene (PS) plastics, which are used to make electronic casings, household textiles, furniture upholstering and building insulation. BFRs are known to be released from the products they are used in[8, 9]. Moreover, other harmful brominated substances such as brominated dioxins (PBDD/Fs) occur as unintentional by-products of BFR application in the products[10].

Worldwide, TBBA is the flame retardant produced in the largest volumes. TBBA is a known endocrine disrupting chemical[11, 12]. PBDEs and HBCD are persistent organic pollutants (“POP-BFRs”), known to disrupt human endocrine, immune and reproductive systems. They negatively affect development of the nervous system and can negatively impact the IQ of children[5, 6, 13, 14]. Humans are exposed to PBDEs through several routes including through food, dust ingestion and through dermal exposure[9]. PBDEs and HBCD have been found in the Arctic region and oceans since they decompose very slowly under natural conditions and are able to travel far from their place of origin through water and air currents[15].

Since regulatory measures for PBDEs and HBCD have increased, novel BFRs (nBFRs), including BTBPE (1,2-Bis(2,4,6-tribromophenoxy) ethane) and OBIND (Octabromo-1,3,3,-trimethylphenyl-1-indan), are increasingly used as substitutes. Studies on the nBFRs have, however, shown that they have properties like those of persistent organic pollutants (i.e., they are extremely slow to degrade, and are found in the Arctic due to their ability to travel long-distances)[16-18]. Very little information has been made available about their hazard characteristics. Because of these properties, they can be considered regrettable substitutes of PBDE.

RECYCLING OF POP-BFRs CREATES A TOXIC LOOPHOLE

Despite existing international controls, many studies have shown the presence of PBDEs and HBCD in new products and household equipment[19, 20], including children's toys[20-24], thermo cups, kitchen utensils[23, 25, 26], office utensils[20] and carpet padding[27, 28]. A study by IPEN and Arnika in 2018 showed that TBBPA and nBFRs, in addition to POP-BFRs, were present in consumer products, including children's toys, hair accessories, and kitchen utensils[29]. It is noteworthy that the analyzed products did not require fire retardance but still contained BFRs. Several previous studies[19, 22-24, 29-31] have shown that toxic flame retardant chemicals were not intentionally added to the specific consumer products purchased in more than 30 countries in Europe, Asia, Africa, Latin and North America, but were passed on during the recycling of e-waste plastics into new products. This practice contradicts the PentaBDE and OctaBDE listing in Annex A of the Stockholm for global elimination[32]. When these substances were listed in 2009, governments agreed to an exemption, until 2030, that permits recycling of materials such as foam and plastics that contain these substances. Such practice creates a toxic recycling loophole in the global controls and compromises the circular plastics economy.

REGULATORY FRAMEWORK IN CHINA, INDONESIA AND RUSSIA

Russia has not yet ratified any of the POP-BFR amendments to the Stockholm Convention, paving the way for continued imports of these substances. Despite relevant amendments were ratified and monitoring projects realized in Indonesia, any ban or restriction related to POP-BFRs has not been implemented into Indonesian legislation. In China, ban on production, distribution, use, import and export of penta- and octaBDE was implemented and ban on HBCD is expected to follow at the end of 2021. HBCD and DecaBDE were included into the List of Chemicals Prioritized for Control. HBCD is listed into Catalog of Toxic Chemicals Strictly Restricted from Import and Export in China and penta- and octaBDE have been included into the Catalog of Products Prohibited from Export and the Catalog of Products Prohibited from Import. In addition to that, China set series of standards that tend to control POP-BFRs content in selected products.

AIM OF THE STUDY

This study aimed to determine whether children's toys, hair accessories, office supplies and kitchen utensils, sold on Chinese, Indonesian and Russian markets contained BFRs. This would indicate use of recycled, flame-retardant-containing plastics, similar to observations in previous studies[24, 27, 29-31].

All three countries are facing waste management challenges, at the local and national levels. One of many reasons is plastic waste imports with unknown chemical content. The data collected in this study will therefore generate information that can contribute to the setting of appropriate standards and to improve the control over circulation of harmful BFRs in plastic consumer products and waste.

MATERIALS AND METHODS

Throughout October-December 2020, 455 samples of consumer products, made of black plastics, were purchased at markets and stores in China, Indonesia and Russia. Black plastic items were selected since electronic casings are typically black, generating black plastics when recycled. Products that are not required to meet any fire standards were deliberately chosen, so that it could be assumed that any BFRs present were not added to the product but rather followed as a consequence of recycling of plastics containing BFRs. Children´s toys, hair accessories, kitchen utensils and office supplies were of primary interest, because they are used by children and women in reproductive age, who are especially sensitive to BFR exposures[22, 33, 34]. Toys are often in contact with children's mouths, kitchen utensils are in contact with food and hair accessories and office supplies are in contact with skin of women in reproductive age (see Figure 1 for photographs for examples of analyzed products). One item constituted one sample.

X-ray fluorescence, a technique frequently used to determine PBDEs in plastics[35, 36], was used to do a preliminary screening of the plastics using a handheld NITON XL 3t 800 XRF analyser (plastic consumer goods program). Samples that contained a 213 ppm or more of bromine and 64

Figure 1. Examples of analyzed products.

ppm or more of antimony were chosen for further analysis. This screening criteria was applied since bromine is a key component of BFRs and antimony trioxide is a common BFR synergist[37]. Samples were also chosen to cover different countries and sample categories (toys, office supplies, hair accessories, kitchen utensils, and other items). Out of the 455 samples, 73 was selected for lab analysis: 30 samples from Russia, 20 samples from China, and 23 samples from Indonesia (Table 1).

TABLE 1: LAB-ANALYSED SAMPLES PER COUNTRY AND SAMPLE CATEGORY

	Children toys	Office supplies	Hair accessories	Kitchen utensils	Other items	Samples per country
China	5	2	6	2	5	20
Indonesia	10	4	2	1	6	23
Russia	24	0	2	3	1	30
Total number per sample category	39	6	10	6	12	73

The samples were analyzed for the presence of 16 different PBDE congeners[1], based on the components of different commercial BFR mixtures. These included the congeners in the commercial PentaBDE mixture (BDE 28, 47, 49, 66, 85, 99, 100), the OctaBDE mixture (BDE 153, 154, 183, 196, 197, 203,206, 207), and the commercial DecaBDE mixture (BDE 209). The presence of three isomers[2] of HBCD (α-, β-, γ-HBCD), TBBPA was analyzed. Also, the presence of six nBFRs: (1,2-bis(2,4,6-tribromophenoxy) ethane (BTBPE), decabromodiphenyl ethane (DBDPE), hexabromobenzene (HBB), octabromo-1,3,3-trimethylpheny-1-indan (OBIND), 2,3,4,5,6-pentabromoethylbenzene (PBEB), and pentabromotoluene (PBT). All analysis was performed by the laboratory at the University of Chemistry and Technology, Prague, Czech Republic.

Targeted BFRs were isolated by extraction with a n-hexane:dichloromethane mixture (4:1, v/v). Identification and quantification of PBDEs and nBFRs were performed using gas chromatography coupled with mass spectrometry in negative ion chemical ionization mode (GC-MS-NICI). Identification and quantification of HBCD isomers were performed by liquid chromatography interfaced with tandem mass spec-

1 Congeners are chemical substances related to each other by origin, structure and function
2 Isomers are compounds with the same formula but a different arrangement of the atoms in the molecule

trometry with electrospray ionization in negative mode (UHPLC-MS/MS-ESI-). The limit of quantification (LOQ) was 1 ppb for BDE 206 and 207 and 0.5 ppb for the other analyzed PBDE congeners and BFRs. Profiles of analyzed BFRs are provided in Annex 1.

RESULTS AND DISCUSSION

Laboratory analysis of the 73 samples revealed that all analyzed samples contained POP-BFRs (see Annex 2 for detailed results). All samples contained octaBDE at concentrations ranging from 0.008 to 261.7 ppm and 72 samples contained decaBDE at concentrations ranging from 0.088 to 442.6 ppm. HBCD and pentaBDE were only detected at very low concentrations, which is expected since these flame retardants are primarily used in polystyrene insulation and foam products and not in electronic casings. None of the samples were required to meet any fire safety standards. In addition, the measured levels of BFRs do not provide a fire-retardant function. Therefore, it is likely that the BFR content comes from recycled e-waste plastics. Summary of the POP-BFRs results per country are provided in Table 2.

TABLE 2: POPs-BFRs IN THE SAMPLES (PPM)

Country	PentaPBDE	OctaPBDE	DecaPBDE	ΣPBDEs	HBCD
China (20 samples)	<LOQ	0.029 - 99.58	<LOQ - 316.2	0.023 - 366.2	<LOQ - 4.66
Russia (30 samples)	<LOQ	0.842 - 125.4	1.909 - 442.6	2.752 - 497.4	<LOQ - 3.97
Indonesia (23 samples)	<LOQ - 1.775	0.008 - 261.7	0.088 - 255.7	0.101 - 405.3	<LOQ - 1.51

The composition of BFRs differ between individual samples, without any specific composition or concentration patterns (see Table 3). This suggests that materials from heterogeneous sources have been used to produce the recycled plastics that have likely been used to make these products.

TABLE 3: TBBPA AND NOVEL BFRs (nBFRs) IN THE SAMPLES (PPM)

Country	TBBPA	BTBPE	DBDPE	HBBz	OBIND	PBEB	PBT	Sum of nBFRs
China (20 samples)	0.30 - 290	LOQ - 557	LOQ - 74.9	0.014 - 1.14	LOQ - 422	LOQ	0.003 - 0.48	5.37 - 728
Russia (30 samples)	0.32 - 368	0.10 - 557	5.37 - 83.0	0.003 - 0.44	0.38 - 74.9	LOQ	0.002 - 0.43	5.85 - 655
Indonesia (23 samples)	0.30 - 268	0.09 - 389	LOQ - 65.6	0.001 - 0.34	LOQ - 17.6	LOQ	LOQ - 0.09	1.81 - 408

Table 4 shows that the average concentration of octaBDEs in the samples of children toys were at the same levels as in toys from 26 countries (including China, Indonesia and Russia) studied in 2017[30]. However, decaBDE concentrations were higher in this study. BFR concentrations per sample category are provided in Annex 3.

TABLE 4: COMPARISON OF PBDE CONCENTRATIONS IN CHILDREN'S TOYS BETWEEN 2017 AND 2020 (THIS STUDY) (PPM)

	OctaBDE		DecaBDE	
	2017	2020	2017	2020
China	3 - 58	5 - 94	2 - 36	23 - 136
Indonesia	LOQ - 52	0.008 - 71	LOQ - 63	0.09 - 256
Russia	1 - 362	0.84 - 125	LOQ - 217	1.91 - 304

This study shows that children's toys, hair accessories, office supplies, and kitchen utensils, available on the Chinese, Indonesian and Russian markets, contained brominated flame retardants (BFRs). None of these countries have regulations limiting BFR content in products or waste. However, entry of BFR-containing products on the markets should be prohibited.

All three countries are both producers and potential recipients of e-waste containing POP-BFRs. To stop imports of waste with POP-BFRs, strict limits for POPs content in waste[3] need to be established. The 2017 Conference of Parties to the Basel and Stockholm Conventions suggested using either a 50 ppm or 1,000 ppm limit for POPs waste containing PBDEs[4] (the so-called “low POPs content” level). With the weaker limit of 1,000 ppm, all wastes containing less than 1,000 ppm of PBDEs will be considered “clean” and allowed for export for recycling or disposal. This weak, “low POPs content” level raises concerns since PBDEs are very similar in structure and toxicological profiles to the highly toxic polychlorinated biphenyls (PCBs)[38, 39]. The POPs content level for PCBs in waste under the Conventions is 50 ppm and it would therefore be consistent for PBDEs also have a 50 ppm limit[40]. Of the analyzed products in this study 62 out of 73 (85 %) would be categorized as POPs waste using a 50ppm limit. Moreover, a weak “low POPs content” level above 50 ppm would lead to decreasing demand for superior waste disposal technologies with the ability to fully destroy BFRs in the waste while not emitting any unintentionally produced POPs (U-POPs). Truly environmentally sound BFR destruction technologies exclude incineration processes. Although Russia and China have the technical capability and pilot plants, they have not yet invested sufficiently to establish commercial non-combustion plants for POP destruction.

RECOMMENDATIONS FOR PARTIES TO THE BASEL AND STOCKHOLM CONVENTIONS AND FOR NATIONAL GOVERNMENTS:

Apply a class-based approach for restricting all brominated flame retardants

In order to achieve a non-toxic circular economy, it is crucial to apply a class-based approach that prevents use of regrettable substitutes to POP-BFRs that are potentially just as harmful, although not yet regulated. A class approach to phase out all BFRs is the only adequate response to prevent further harm to human health and the environment.

3 The Stockholm Convention requires that POPs wastes be treated so that POP content is destroyed or irreversibly transformed to that they no longer exhibit POPs characteristics. The Convention sets low POPs content limits (LPCL) above which treatment is required. POPs waste is prohibited to be recycled and cannot be transported across the international borders of the countries– see Article 6 of the Stockholm Convention.

4 Revised draft general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (General technical guidelines), version of March 2018 available at: http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/TechnicalGuidelines(versionMarch2018)/tabid/6303/Default.aspx

Set protective environment-and health limits for POPs wastes under the Basel Convention

Parties to the Stockholm and Basel Conventions should adopt the scientifically and environmentally sound limits of 50 ppm for PBDEs and 100 ppm for HBCD in waste. Only a strict, "low POPs content" level will ensure separation of PBDE- and HBCD-treated products from the recycling stream when they become waste. Waste containing these substances in concentrations over the "low POPs content" level must be managed in an environmentally sound manner in line with the Conventions, i.e., POPs in waste must be destroyed or irreversibly transformed. This hazardous waste should not be allowed for export to countries that lack appropriate, truly environmentally sound, POPs destruction technologies.

Establish appropriate separation techniques for POP-BFRs

Until products are produced without these toxic substances, separation techniques should be used to remove items containing PBDEs and other toxic substances before recycling. In the informal plastic recycling sector in India, a simple sink and float method is used for separation of BFR-treated plastics[45]. In Europe, X-ray fluorescence (XRF) and X-ray transmission (XRT), are used to measure total bromine concentrations, and are operated on an industrial scale[45]. Such methods can be used globally, including controls of imported waste at the state borders.

Stop e-waste export to developing and transition countries under Basel Convention provisions

E-waste must be clearly defined as hazardous, which will trigger export prohibitions from OECD to non-OECD countries under the Basel Convention Ban Amendment. In addition, The Basel Convention e-waste guidelines must be modified to prevent the export of e-waste to any country that lacks regulatory infrastructure and technical and economic capacities for hazardous waste management.

CONCLUSIONS

This study shows that children's toys, hair accessories, office supplies and kitchen utensils, available on the Chinese, Indonesian and Russian markets, contained brominated flame retardants (BFRs). The BFRs were likely originating from unregulated recycling of e-waste plastics. This practice contaminates and compromises a circular plastic economy, which means that production of plastics containing hazardous chemicals cannot continue. Application of a class-based-approach that restricts use of all POP-BFRs, including regrettable substitutes that are currently used in products in the targeted countries without any regulation, monitoring or control would significantly contribute to an increased circularity. Also, existing contaminated materials must be separated from the waste stream and POP-chemicals destroyed or irreversibly transformed to stop further spreading of POP-BFRs. One crucial initial step towards a non-toxic circular economy is to set a strict, low POPs content limit for wastes. This limit should be set at a concentration that prevents recycling of POP-BFRs into new products and stops the export of POP-BFR contaminated wastes into developing and transition countries.

ANNEX 1: BFR PROFILES

POLYBROMINATED DIPHENYLETHERS (PBDES)

PBDEs are divided into few groups due to the number of halogens, it includes PentaBDE (BDE congeneres 82-127), OctaBDE (BDE congeners 194–205) and DecaBDE (BDE congener 209).

Pentabromodiphenyl ether (pentaBDE) has been used extensively in textiles and polyurethane foam, but also appears in electronics. Octabromodiphenyl ether (octaBDE) has been used in acrylonitrile butadiene styrene (ABS) and other plastics used in electronics such as office equipment. Decabromodiphenyl either (decaBDE) is widely found in plastics used in electronics and is a common component of electronic waste.

These chemicals are known to disrupt human hormone systems, adversely impacting the development of the nervous system and children's intelligence[7, 46, 47]. Due to these harmful effects and bioaccumulative properties, PBDEs were put under the radar of environmental authorities (e.g., the European REACH regulation and Stockholm Convention). PBDEs are lipophilic and have some structural similarities to PCB and PCDD/F.

HEXABROMOCYCLODODECANE (HBCD OR HBCDD)

The commercial HBCD product is composed of three diastereomers: α-, β-, and γ-HBCD. Technical HBCD typically consists primarily of γ-HBCD[48].

Hexabromocyclododecane (HBCD or HBCDD) was mainly applied in extruded and expanded polystyrene foam for building insulation and expanded polystyrene, but also in video cassette recorder housing and electronics. End products include upholstered furniture, interior textiles, automobile interior textiles, car cushions and insulation blocks in trucks and caravans as well as in building materials such as house walls, cellars, roofs and parking decks, as part of infrastructure units, is also found in packaging material, video cassette recorder housing, and electric equipment[29].

HBCD is highly toxic to aquatic organisms and has negative effects on reproduction, development, and behavior in mammals, including transgenerational effects[6]. In fact, HBCD is bioaccumulative and persistent, with a half-life of 3 days in air and 2–25 days in water[49].

TETRABROMOBISPHENOL A (TBBPA)

Tetrabromobisphenol A (TBBPA) is the largest-volume flame retardant used worldwide[11] covering around 60% of the total global BFR market[50], While then majority of TBBPA is chemically bonded to the polymer matrix of printed circuit-boards, it is also applied as an additive flame retardant in the manufacture of ABS resins and HIPs as an alternative to PBDEs and HBCD, and to banned OctaBDE mixtures in ABS plastic in particular[51, 52]. ABS resins are used in automotive parts, pipes and fittings, refrigerators, business machines, and telephones.

The main applications where plastic containing TBBPA may be used include TV-set back-casings and business equipment enclosures. TBBPA is cytotoxic, immunotoxic, and a thyroid hormone agonist with the potential to disrupt estrogen signaling[12, 48]. TBBPA is classified as very toxic to aquatic organisms and is on the OSPAR Commission's List of Chemicals for Priority Action due to its persistence and toxicity[53].

NOVEL BROMINATED FLAME RETARDANTS (nBFR)

The various alternative halogenated flame retardants, known as novel brominated flame retardants (nBFRs), have been used or recently introduced by the industry to replace PBDEs. Overall, the nBFRs marketed as flame retardants lack adequate toxicity information. However, the available information has raised concerns. Some of the nBFRs are persistent, bio-accumulative and travel long distances and moreover are likely to be released to the environment by the same mechanisms as PBDEs and share a similar fate as persistent pollutants in air, soil and sediments. Despite these toxicological concerns and the lack of comprehensive information, nBFRs continue to be used as PBDEs substitutes.

The brief overview presented below relates to the most widely used nBFR[54].

DECABROMODIPHENYLETHANE (DBDPE)

DBDPE is a commercially important alternative to decaBDE used in plastic casings for televisions and in a range of other plastics, resins, rubbers, adhesives and textile products. A significant property of this substance is the ability to be transported for long distances[55].

1,2-BIS(2,4,6-TRIBROMOPHENOXY) ETHANE (BTBPE)

BTBPE is one of the new flame retardants that replaced OctaBDE. It is used in the plastic casings of computers, TVs and mobile phones. This compound can bioaccumulate and biomagnify in in fish[56, 57].

OCTABROMO-1,3,3,-TRIMETHYLPHENYL-1-INDAN (OBIND)

OBIND is another replacement for PBDEs that is used in different plastics of electronic products. OBIND has been found in bird eggs[58]. There is very little publicly known information about its toxicity.

2,3,4,5,6-PENTABROMOETHYLBENZENE (PBEB)

PBEB is a flame retardant that was used mainly in the 1970s and 1980s under the name FR-105. It was used in polymers and has been poorly characterized toxicologically, but the substance is a brominated analogue of ethyl benzene, a carcinogen[29].

PENTABROMOTOLUENE (PBT)

PBT is used in polystyrene casings for electronics, ABS plastics and other plastic polymers, and sold under the name FR-105 or Flammex. Studies confirmed histologic changes in laboratory rats; however, other than this fact, there is extraordinarily little officially known about this substance. A significant property of this substance is the ability to be transported for long distances[55].

HEXABROMOBENZENE (HBB)

HBB is a retardant applied to electronics. HBB has commonly been used for the manufacture of paper, woods, textiles, plastics, and electronic goods[59, 60]. A significant property of this substance is the ability to travel long distances[55].

ANNEX 2: BFRs IN ANALYZED PRODUCTS (ppm)

Sample category: Toy=children toy, Hair=hair accessories, Kitchen=kitchen utensils, Office=office supplies, Other=other items

<LOQ=below limit of quantification

Sample ID	Sample category	Sample decription	PentaPBDE	OctaBDE	DecaPBDE	Sum of HBCD	Sum of nBFRs	TBBPA
CHN-BFR-70	Toy	Toy accordion	<LOQ	43.2	96.4	0.48	254	109
CHN-BFR-142	Toy	Toy gun	<LOQ	94.0	136	1.29	281	69.2
CHN-BFR-129	Hair	Hairband	<LOQ	67.0	113	0.51	112	87.9
CHN-BFR-10	Kitchen	Extension clamp	<LOQ	6.50	90.8	<LOQ	77.3	1.90
CHN-BFR-91	Other	Mobile phone holder	<LOQ	7.38	60.5	<LOQ	80.9	33.0
CHN-BFR-141b	Office	Pen	<LOQ	57.4	134	0.26	92.9	47.9
CHN-BFR-140	Hair	Hairclip	<LOQ	99.6	69.7	1.26	728	290
CHN-BFR-12	Kitchen	Soup ladle	<LOQ	5.46	57.7	<LOQ	7.15	1.07
CHN-BFR-132	Other	Mobile phone holder	<LOQ	74.2	107	4.66	468	62.1
CHN-BFR-01	Hair	Comb	<LOQ	16.8	183	0.20	23.4	101
CHN-BFR-82	Hair	Hearband	<LOQ	48.4	77.0	0.65	87.4	76.7
CHN-BFR-81	Hair	Hairclip	<LOQ	22.4	270	0.53	68.8	33.1

Sample ID	Sample category	Sample decription	PentaPBDE	OctaBDE	DecaPBDE	Sum of HBCD	Sum of nBFRs	TBBPA
CHN-BFR-98	Other	Pump	<LOQ	14.0	231	0.44	13.6	4.42
CHN-BFR-108	Toy	Memory game	<LOQ	18.9	85.9	<LOQ	108	45.6
CHN-BFR-76	Other	Lock	<LOQ	13.3	75.8	<LOQ	62.8	71.6
CHN-BFR-37	Hair	Hairclip	<LOQ	1.42	10.0	<LOQ	14.7	4.53
CHN-BFR-54	Office	Pen	<LOQ	50.0	316	<LOQ	112	121
CHN-BFR-45	Toy	Toy car	<LOQ	5.00	22.9	<LOQ	57.6	53.8
CHN-BFR-42	Other	Rubber sole	<LOQ	0.02	LOQ	<LOQ	5.37	<LOQ
CHN-BFR-107	Toy	Toy car	<LOQ	19.2	57.2	<LOQ	95.13	92.9
RUS-BFR-103	Toy	Toy car	<LOQ	14.8	107	<LOQ	57.4	54.1
RUS-BFR-104	Toy	Toy gun	<LOQ	20.4	232	0.68	51.6	30.9
RUS-BFR-107	Toy	Toy gun	<LOQ	125	180	1.16	166	116
RUS-BFR-121	Toy	Toy car	<LOQ	30.7	249	0.46	45.1	75.1
RUS-BFR-122	Toy	Toy car	<LOQ	31.9	120	<LOQ	94.4	49.5
RUS-BFR-131	Toy	Toy car	<LOQ	10.6	38.9	<LOQ	54.2	34.1
RUS-BFR-133	Toy	Toy car	<LOQ	15.8	77.4	<LOQ	50.0	65.3
RUS-BFR-134	Toy	Toy car	<LOQ	0.84	1.91	<LOQ	5.85	<LOQ
RUS-BFR-142	Toy	Toy gun	<LOQ	119	64.2	3.97	361	249
RUS-BFR-144	Toy	Toy gun	<LOQ	52.4	261	<LOQ	89.8	79.0

Sample ID	Sample category	Sample decription	PentaPBDE	OctaBDE	DecaPBDE	Sum of HBCD	Sum of nBFRs	TBBPA
RUS-BFR-145	Toy	Toy gun	<LOQ	3.55	22.1	<LOQ	38.2	51.5
RUS-BFR-150	Toy	Toy gun	<LOQ	43.2	146	0.52	70.4	52.0
RUS-BFR-25	Hair	Comb	<LOQ	54.8	443	0.59	160	273
RUS-BFR-35	Hair	Hairclip	<LOQ	53.4	159	0.27	106	53.3
RUS-BFR-42	Other	Box for batteries	<LOQ	47.6	278	<LOQ	89.1	297
RUS-BFR-43	Toy	Toy construction set	<LOQ	76.6	231	1.55	655	257
RUS-BFR-46	Kitchen	Handle	<LOQ	13.2	93.1	<LOQ	77.6	29.6
RUS-BFR-50	Toy	Rubik's like cube	<LOQ	46.8	117	<LOQ	98.6	145
RUS-BFR-67	Toy	Rubik's like cube	<LOQ	6.56	34.5	<LOQ	57.3	17.9
RUS-BFR-73	Toy	Rubik's like cube	<LOQ	8.81	46.9	<LOQ	55.2	41.7
RUS-BFR-74	Toy	Rubik's like cube	<LOQ	98.7	253	<LOQ	246	368
RUS-BFR-79	Kitchen	Handle	<LOQ	69.2	255	0.72	217	104
RUS-BFR-80	Kitchen	Handle	<LOQ	58.8	124	0.78	163	115
RUS-BFR-84	Toy	Toy gun	<LOQ	19.7	76.3	0.67	50.8	32.4
RUS-BFR-85	Toy	Toy gun	<LOQ	103	212	0.76	237	107
RUS-BFR-86	Toy	Toy gun	<LOQ	97.9	169	0.94	145	194
RUS-BFR-143	Toy	Toy batman	<LOQ	5.91	80.5	<LOQ	31.9	16.7

Sample ID	Sample category	Sample decription	PentaPBDE	OctaBDE	DecaPBDE	Sum of HBCD	Sum of nBFRs	TBBPA
RUS-BFR-53	Toy	Rubik's like cube	<LOQ	13.3	158	<LOQ	90.3	24.4
RUS-BFR-96	Toy	Toy robot	<LOQ	11.2	190	<LOQ	8.26	0.79
RUS-BFR-68	Toy	Rubik's like cube	<LOQ	25.3	304	<LOQ	32.3	7.12
IDN-BFR-62	Office	Brush	<LOQ	7.54	136	<LOQ	11.0	1.75
IDN-BFR-77	Other	Bottle holder	<LOQ	0.63	1.97	<LOQ	10.5	0.54
IDN-BFR-18	Toy	Abacus	<LOQ	47.0	44.5	1.51	83.1	38.1
IDN-BFR-142	Toy	Toy car	<LOQ	6.21	48.1	<LOQ	17.0	55.8
IDN-BFR-87	Kitchen	Kitchen tongs	<LOQ	5.72	65.6	<LOQ	7.72	<LOQ
IDN-BFR-148	Toy	Toy robot	<LOQ	8.39	188	0.35	14.9	14.9
IDN-BFR-76	Other	Selfie stick	<LOQ	32.9	85.5	0.62	87.1	51.8
IDN-BFR-98	Toy	Toy gun	<LOQ	71.1	71.4	0.61	116	78.7
IDN-BFR-83	Toy	Toy car	<LOQ	28.6	101	<LOQ	104	126
IDN-BFR-85	Other	Dye bowl	<LOQ	9.35	0.09	<LOQ	22.7	<LOQ
IDN-BFR-32	Toy	Toy telescope	<LOQ	0.01	0.09	<LOQ	1.81	1.38
IDN-BFR-59	Office	Carpenters tape	<LOQ	15.9	58.3	<LOQ	18.8	22.2
IDN-BFR-95	Hair	Hairclip	0.20	262	143	<LOQ	24.6	29.6
IDN-BFR-20	Hair	Hairclip	<LOQ	7.71	93.7	0.22	22.7	9.9
IDN-BFR-104	Office	Magnifier	<LOQ	8.04	38.5	<LOQ	43.6	27.9

Sample ID	Sample category	Sample decription	PentaPBDE	OctaBDE	DecaPBDE	Sum of HBCD	Sum of nBFRs	TBBPA
IDN-BFR-45	Toy	Toy gun	<LOQ	19.2	256	0.21	22.8	7.25
IDN-BFR-96	Toy	Rubik's like cube	<LOQ	12.5	159	<LOQ	37.6	0.90
IDN-BFR-115	Toy	Toy water spray	<LOQ	5.40	117	<LOQ	18.3	5.99
IDN-BFR-69	Toy	Toy car	<LOQ	15.8	81.6	0.96	35.0	13.3
IDN-BFR-41	Other	Tasbih	1.74	97.7	149	<LOQ	408	152
IDN-BFR-106	Other	Photo frame	<LOQ	85.7	187	0.24	99.3	52.3
IDN-BFR-61	Other	Phone tripod	1.23	44.5	71.8	<LOQ	70.3	268
IDN-BFR-88	Office	Cutter	<LOQ	42.1	58.9	1.17	85.3	55.4

ANNEX 3: RANGES OF BFR CONCENTRATIONS PER SAMPLE CATEGORY (ppm)

	Children's toys	Hair accessories	Kitchen utensils	Office supplies	Other products
Number of samples	39	10	6	6	12
OctaBDE	0.008 - 125	1.42 - 262	5.46 - 69	7.54 - 57.4	0.02 - 97.7
DecaBDE	0.09 - 304	10 - 442	58 - 255	38.5 - 316	LOQ - 278
ΣPBDEs	0.10 - 351	11 - 497	63 - 324	46.5 - 366	0.02 - 326
HBCD	LOQ - 3.97	LOQ - 1.26	LOQ - 0.78	LOQ - 1.17	LOQ - 4.66
ΣnBFRs	1.81 - 655	14.7 - 727	7.15 - 217.4	11.0 - 112	5.37 - 468
TBBPA	0.32 - 368	4.53 - 290	0.38 - 115	1.75 - 120.5	0.30 - 297
ΣBFRs	3.07 - 1220	30.6 - 1188	134 - 460	115 - 599	5.69 - 808
Total Br	307 - 19900	418 - 18567	342 - 3890	374 - 6114	213 - 16967

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