POPS RECYCLING CONTAMINATES CHILDREN'S TOYS WITH TOXIC FLAME RETARDANTS

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Established in 1998, **IPEN** is currently comprised of over 500 Participating Organizations in 116 countries, primarily developing and transition countries. IPEN brings together leading environmental and public health groups around the world to establish and implement safe chemicals policies and practices that protect human health and the environment.IPEN's mission is a toxics-free future for all.

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EXECUTIVE SUMMARY

Recycling plastics containing toxic flame retardant chemicals found in electronic waste results in contamination of new plastic children's toys and related products. The substances include octabromodiphenyl ether (OctaBDE), decabromodiphenyl ether (DecaBDE), and hexabromocyclododecane (HBCD). This study found all three toxic chemicals in recycled plastic children's products. In a survey of products from 26 countries, 90% of the samples contained OctaBDE or DecaBDE. Nearly half of them (43%) contained HBCD. Recycling materials that contain persistent organic pollutants (POPs) and other toxic substances contaminates new products, continues human and environmental exposure, and undermines the credibility of recycling.

OctaBDE and DecaBDE are widely used in electrical equipment and are primary toxic components of electronic waste (e-waste). HBCD is primarily used in polystyrene building insulation but is also found in electronic equipment. Both HBCD and OctaBDE are listed in the Stockholm Convention for global elimination. DecaBDE is recommended for listing in the treaty for elimination and governments will make the decision at the 8th Conference of the Parties (COP8) in April 2017. Note that OctaBDE is subject to an exemption that permits recycling of materials containing the substance. The treaty's expert committee has warned against this practice and COP8 will decide whether to continue it. The expert committee explicitly recommended to "*…eliminate brominated diphenyl ethers from the recycling streams as swiftly as possible*" noting that, "*Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling*" (UNEP/POPS/COP.5/15).

The Stockholm Convention contains hazardous waste limits known as "low POPs content" levels that define the value at which wastes are considered to be POPs wastes and therefore must be addressed according to strict treaty obligations. The final limits for listed substances such as OctaBDE and HBCD will be decided at COP8. The limit for DecaBDE will be decided later if listed. This study found samples of children's products exceeding proposed and existing hazardous waste limits. For example, 43 samples (39%) contained OctaBDE at levels greater than 50 ppm – one of the proposed hazardous waste limits. One sample exceeded the higher proposed limit of 1000 ppm. For HBCD, 7 samples (7%) contained HBCD at concentrations higher than 100 ppm – one of the proposed hazardous waste limits. Two samples exceeded the higher proposed level of 1000 ppm. Finally, 48 samples (43%) contained DecaBDE at levels that exceeded the current hazardous waste limit for PCBs, which they strongly resemble in structure and adverse effects. The data illustrates the importance of protective hazardous waste limits since weak standards could encourage toxic recycling and waste dumping in the absence of national regulations prohibiting the practices.

Two Stockholm Convention measures that could help address toxic recycling are: 1) to end the current recycling exemptions and avoid new ones including in the listing decision on DecaBDE; and 2) set protective limits for substances in wastes so that they are subjected to treaty obligations for destruction. Sustainable waste management and a circular economy are not compatible with toxic chemicals being recycled into new consumer products.

IPEN RECOMMENDATIONS

- COP8 should end the toxic recycling exemption for brominated diphenyl ethers in parts IV and V of Annex A.
- Parties should not create a recycling exemption for materials containing DecaBDE.
- COP8 should adopt the following low POPs content levels:
  - **HBCD**: 100 mg/kg (100 ppm)
  - **OctaBDE (HexaBDE and HeptaBDE)**: 50 mg/kg (50 ppm)
  - **PCBs**: 10 mg/kg (10 ppm)

INTRODUCTION

Brominated flame retardants have been widely added to foam and plastics used in consumer and electronic products. Pentabromodiphenyl ether (PentaBDE) has been used extensively in 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. Hexabromocyclododecane (HBCD or HBCDD) was mainly applied in extruded and expanded polystyrene foam for building insulation, but also in video cassette recorder housing and electronics. These chemicals are known to disrupt human hormone systems, adversely impacting the development of the nervous system and children's intelligence. Commercial PentaBDE, commercial OctaBDE, and HBCD are listed in Annex A of the Stockholm Convention for global elimination. Governments will decide on adding DecaBDE to Annex A at COP8 in April 2017.

Plastics or other materials containing POPs could be subject to the treaty's waste provisions depending on their levels of contamination. The Stockholm Convention contains hazardous waste limits known as "low POPs content" levels (LPCL) that define the value at which wastes are considered to be POPs wastes according to the concentration of POPs they contain. Wastes containing POPs above the LPCL must be addressed according to strict treaty obligations. Weak standards could encourage toxic recycling and waste dumping in the absence of national regulations prohibiting the practices.

In 2009, COP4 created an exemption that permits recycling of plastics, foam, and other materials containing commercial PentaBDE and OctaBDE until 2030. Due to concerns about the possible impacts of this recycling exemption, COP4 requested the treaty's expert committee to examine its implications. Subsequently, the expert committee known as the POPs Review Committee (POPRC), developed recommendations on the recycling exemption for COP5. The Committee warned against the practice and recommended to, "*…eliminate brominated diphenyl ethers from the recycling streams as swiftly as possible*" noting that, "*Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling*" (UNEP/POPS/COP.5/15). The recycling issue is especially relevant to DecaBDE due to widespread informal sector recycling of e-waste in developing countries.

This study asked whether flame retardants found in e-waste are carried into new consumer products as a result of plastic recycling as predicted by the POPs Review Committee technical report. We examined OctaBDE, HBCD, and DecaBDE in Rubik's cubes, a children's product usually made of recycled plastic, along with several other types of plastic toys.

MATERIALS AND METHODS

Rubik's cubes and several other consumer goods were screened for bromine using a handheld XRF analyzer to identify samples with significant bromine levels (hundreds of ppm). Positive samples were analyzed for PBDEs and HBCD at the Institute of Chemical Technology, an accredited laboratory in the Czech Republic. Brominated flame retardants were extracted by n-hexane and the leachate transferred into isooctane. Identification and quantification of flame retardants was accessed via gas chromatography/mass spectrometry in the mode of electron ionization (GC-MS/MS-EI). The main components of congeners listed in the Stockholm Convention were analyzed with a detection limit of 0.1 ppb for PBDEs and 3 ppb for HBCD.

RESULTS

Laboratory analysis of 95 Rubik's cubes and 16 additional samples (including a thermo cup, hair clips, combs, headdresses, and children's toys) from 26 countries in various regions found 100 samples (90%) contained OctaBDE at concentrations ranging from 1 to 1174 ppm. Ranges of the measured concentrations per country are summarized in Table 1 (Annex 1). Forty-three samples (39%) contained OctaBDE at levels greater than 50 ppm – one of the LPCL proposed for PBDEs listed in the Stockholm Convention. One sample exceeded the higher proposed LPCL of 1000 ppm.

Results shown in Tables 1 and 2 (Annex 1) demonstrate that forty-five samples (43%) contained HBCD at concentrations ranging from 1 to 1586 ppm. In products in which it was measured, seven samples (7%) contained HBCD at concentrations higher than 100 ppm – the provisional LPCL. Two samples exceeded the higher proposed level of 1000 ppm.

One-hundred-one samples (91%) contained DecaBDE at concentrations ranging from 1 to 672 ppm (Tables 1 and 2 in Annex 1). Forty-eight of the samples (43%) contained DecaBDE at levels greater than 50 ppm. Note that the provisional definition for LPCL for DecaBDE has not yet been set but PBDEs strongly resemble PCBs which have a provisional LPCL of 50 ppm. A lower proposed LPCL limit of 10 ppm for PCBs has been proposed and 76 samples (68%) containing DecaBDE exceeded this limit.

Overall, the results indicate that toxic flame retardant chemicals found in e-waste are widely present in children's toys made of recycled plastic. Many children's products contained significant levels of these substances of 50 ppm or greater. This includes two substances listed in the Stockholm Convention (OctaBDE and HBCD) and a third flame retardant up for a listing decision at COP8 (DecaBDE).

DISCUSSION

The data demonstrates that toxic flame retardant chemicals found in e-waste are widely present in plastic children's products such as Rubik's cubes, car toys, or children's hair accessories. The results are consistent with the study of Chen et al. (2009) which found PentaBDE, OctaBDE, DecaBDE and other flame retardants in 80% of sampled plastic children's toys. This survey also complements a recent study by Samsonek and Puype (2013) which found flame retardants from electronic waste recycled into plastic food contact materials such as thermo cups and kitchen utensils. A follow-up study in 2015 found DecaBDE in food contact materials on the EU market such as thermo-cup lids and an egg cutter made from recycled plastic (Puype et al. 2015). An analysis of toys made of recycled plastic on the market in Belgium found commercial PentaBDE, OctaBDE, and DecaBDE (Ionas et al. 2014). A single OctaBDE congener was found in 22% of the toys and DecaBDE was found in 16% of them. This is consistent with an analysis of the PentaBDE and OctaBDE (POP-BDEs) stream in the Netherlands by Leslie et al. (2013) which found that 22% of the POP-BDEs in waste electrical and electronic equipment is expected to end up in recycled plastics. In Australia, an analysis of 1714 plastic products or components of TVs and small appliances found OctaBDE congeners in 31% of them at levels ranging from 51 – 6805 ppm (Gallen et al. 2014). A Stockholm Convention secretariat review of this issue noted that these levels (and the ones found this study) are below those needed for flame retardancy suggesting that the substances were present as a result of recycling (UNEP/POPS/COP.8/INF/12). The problem of recycling materials containing POPs and contaminating new products also occurs in recycled foam products such as carpet padding (DiGangi et al. 2011). Two key aspects to address the toxic recycling issue in the Stockholm Convention are the values set for LPCL and the recycling exemption.

LOW POPS CONTENT LEVELS AND POPS WASTES

The Stockholm Convention aims to reduce and eliminate all releases of POPs and includes measures to address releases from stockpiles and wastes in Article 6. This includes establishment of LPCLs which are a crucial tool to control potential releases of POPs due to improper handling of POPs wastes. LPCLs define the value at which wastes are considered to be POPs wastes and therefore must be "Disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed" (Stockholm Convention Article 6.1 d ii). Thus, LPCLs are crucial for defining which wastes are hazardous according their POPs content. The accompanying technical guidelines are important for providing appropriate methods and options for POPs waste disposal. In the absence of national regulations, strict LPCLs may be the only mechanism to prevent widespread transboundary movements of POPs-contaminated products and wastes, accelerating the rate and scope of human exposure to POPs. Strict LPCLs will also restrict the amount of contaminated materials entering the recycling chain.

NEW PROPOSALS FOR LOW POPS CONTENT LEVELS DECIDED AT COP8

The values assigned to LPCLs for all listed POPs will be decided at COP8 (for proposed definitions see UNEP-CHW.13-INF-66). All LPCLs are important, but the levels for OctaBDE, HBCD, and PCBs are especially relevant for this study. PCBs are relevant because they are closely related to DecaBDE in structure and adverse effects which should result in similar LPCLs being adopted for both chemicals. Proposals for the decision on LPCLs at COP8 were developed by a Basel Convention Small Intersessional Working Group.

There are two LPCL proposals for OctaBDE and two for HBCD. The proposal for the OctaBDE LPCL combines two OctaBDE congeners (HexaBDE and HeptaBDE) and the two listed PentaBDE congers (TetraBDE and PentaBDE). Delegates at COP8 will decide on a proposed LPCL of either 50 ppm or 1000 ppm as a sum of all four congeners (UNEP-CHW.13-INF-66). These numbers come from a comprehensive report elaborated by EU consultants (ESWI and BiPRO 2011). The report initially recommended using a provisional LPCL of 200 ppm for the four individual substances which is the origin of the 1000 pm LPCL proposal. However, the report noted that these initial levels were only intended to be for a "restricted time frame in order to facilitate enforcement" (ESWI and BiPRO 2011). Lower levels were proposed for greater protection of human health and then environment. The consultants proposed lowering the threshold to 10 ppm for each of the four PBDE substances by 2016 which is the origin of the Basel Working Group's proposal of 50 ppm LPCL. IPEN supports the 50 ppm LPCL for PBDEs as a sum. A similar process prompted the EU consultants to update the LPCL limit for HBCD to 100 ppm from the current provisional limit of either 100 ppm or 1000 ppm. IPEN supports the 100 ppm LPCL limit for HBCD. The impact of the LPCL proposals can be seen in the presented data. If the LPCL for PentaBDE/OctaBDE is 50 ppm, then forty-three samples (39%) exceed it. In contrast, if the LPCL is 1000 ppm, then only 1 sample exceeds the LPCL limit. In a like manner, 7 samples exceeded a LPCL for HBCD of 100 ppm but only 2 samples would exceed a 1000 ppm LPCL in this study.

There are also two LPCL proposals for PCBs– 50 ppm (current provisional limit) or 10 ppm (new proposal). IPEN supports the 10 ppm limit for greater health protection. The 10 ppm LPCL for PCBs was proposed on the basis that PCBs and polychlorinated naphthalenes (PCNs) have very similar structure and toxicity and the proposed LPCL for PCN is 10 ppm. The same logic should apply to DecaBDE. The Stockholm Convention expert group noted that DecaBDE is structurally similar to PCBs and have been produced on a similar scale (UNEP/POPS/POPRC.10/10/Add.2). Earlier, the Committee noted that, "The neurotoxic effects of PBDEs are similar to those observed for PCBs and so children exposed to PBDEs are likely to be prone to subtle but measurable developmental problems" (UNEP/POPS/POPRC.2/17/Add.1). In this study, 48 samples (43%) contained DecaBDE at levels greater than the current provisional LPCL of 50 ppm. Seventy-six samples (68%) contained DecaBDE at levels greater than the proposed 10 ppm LPCL.

IMPLICATIONS OF LOW POPS CONTENT LEVELS

If weak LPCLs are adopted, then more POPs can flow into consumer products and transboundary movement of POPs in contaminated materials such as e-waste, incineration residues, polystyrene, or polyurethane foam will expand and accelerate. The flow of this contaminated material is likely to be from developed countries to developing countries where management costs are lower and regulations weaker. If this is allowed to happen then the objectives of the Stockholm and Basel Conventions will be permanently undermined at the expense of human health and the environment. This effect has already been demonstrated by Breiviket al. (2011) due to POPs waste export from developed countries to Africa and Asia. A secretariat review of PentaBDE and OctaBDE elimination noted that, "It is estimated that at least 50 % of WEEE [waste electrical and electronic equipment] is collected outside of the official take-back systems in the EU, part of which is then exported to developing countries as used equipment or illegally. Illegal shipments originate mainly from Europe, North America, Japan, Australia and the USA with common destinations in Asia (including China, Hong Kong, India, Pakistan and Vietnam) and Africa (including Ghana, Nigeria, and Benin). In addition to WEEE, plastics from WEEE are also reported to be exported to developing countries in Asia" (UNEP/POPS/COP.8/INF/12). A weak LPCL will enshrine this arrangement and unnecessarily expose new populations to POPs when contaminated materials are shipped as recycled materials or other products without restriction.

RECYCLING EXEMPTION FOR MATERIALS CONTAINING PENTABDE AND OCTABDE

In 2009, COP4 created an exemption that permitted recycling of plastics, foam, and other materials containing PentaBDE and OctaBDE until 2030. Due to concerns about the possible impacts of this recycling exemption, COP4 requested the treaty's expert committee to examine its implications. Subsequently, the expert committee known as the POPs Review Committee (POPRC) developed recommendations on the recycling exemption for COP5. The Committee warned against the practice and recommended to "...eliminate brominated diphenyl ethers from the recycling streams as swiftly as possible" noting that, "Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling" (UNEP/POPS/COP.5/15).

RECYCLING EXEMPTION FOR HBCD REJECTED

In 2012, in its review of HBCD releases, the POPRC noted that, "the releases from PS foam and recycling of electronic and electrical products in developing countries are of importance" (UNEP/POPS/POPRC.7/19/Add.1). The Committee further expressed concern about recycling materials containing HBCD noting that, "HBCD will likely be spread into articles that will be difficult to identify, as previously determined by the POPRC for recycling products containing pentaBDE and octaBDE." Increasing the waste burden of POPs in developing countries is another consequence of toxic recycling and exemptions for use. The Committee expressed concern about "articles and products in use containing hexabromocyclododecane being exported, especially to developing countries and countries with economies in transition" (UNEP/POPS/POPRC.8/16). At COP6, delegates rejected a proposal by the EU to allow recycling of products containing HBCD due to concerns expressed by the POPRC in its recommendations and by developing countries at the COP.

EXPERT COMMITTEE WARNS AGAINST DECABDE RECYCLING

The POPRC took up the topic of recycling again in its evaluation of DecaBDE – which is particularly relevant to the informal sector "recycling" of e-waste in developing countries. The DecaBDE Risk Management Evaluation states that, "it is difficult to control the content of c-decaBDE in plastic material destined for recycling and that recycling may contribute to human exposure to c-decaBDE. Monitoring data also shows that recycling contributes to significant environmental pollution and health risks for local populations, particularly in developing countries where recycling occurs in the informal sector" (UNEP/POPS/POPRC.11/10/Add.1). Concerns about developing country capacity to handle imports of DecaBDE also emerged during the Committee's evaluation: "African experts oppose a recycling exemption due to lack of capacity to identify and analyse products containing deca BDE" (UNEP/POPS/POPRC.11/10/Add.1). Finally, the POPRC stated that, "the control measure that most effectively will abate global emissions is to globally ban the production and use of c-decaBDE in articles and avoid recycling of products containing c-decaBDE… this practice will continue to spread c-decaBDE to the environment as well as human exposure" (UNEP/POPS/COP.8/INF/12). Notably, the Committee did not recommend a recycling exemption for DecaBDE.

DECISION ABOUT CONTINUING THE STOCKHOLM CONVENTION RECYCLING EXEMPTION AT COP8

At COP8, delegates will decide whether to continue the recycling exemption for commercial PentaBDE and OctaBDE as required by paragraph 2 of parts IV and V of Annex A. The decision is part of an overall review of how well Parties are progressing in eliminating both substances. The secretariat review noted that, "low levels of POP-BDEs have been detected in a range of articles, including plastic toys that are not subject to flammability requirements, suggesting that their presence was unintentional and possibly a consequence of the recycling of plastics originating from WEEE [waste electrical and electronic equipment]" (Haarman and Gasser 2016).

To prevent toxic recycling, plastics containing flame retardants should be separated. This can be accomplished using handheld XRF devices (x-ray fluorescence) to detect bromine. In addition, a variety of cheap, simple methods exist that are applicable in all countries. These include the Beilstein test to identify halogen-containing plastics and flotation techniques to separate them. Flotation separation techniques have been used by waste pickers in developing countries to separate brominated plastics from clean plastics with a high level of success (Truc et al 2015). They can also be used by the informal plastics recycling sector in India with an average removal efficiency of 96% using a solution of fresh water and table salt (UNEP/POPS/COP.8/INF/12). The technical and economic feasibility of these methods clashes with developed country claims that economic considerations are a barrier to separate materials containing brominated flame retardants (UNEP/POPS/COP.8/INF/12).

The secretariat review notes that a comprehensive analysis of PentaBDE and OctaBDE elimination is not possible. However, it is clear from the secretariat and POPRC reviews that continuing the flow of these substances into new products through recycling is not consistent with Stockholm Convention objectives – especially when widely available, technically and economically feasible methods exist to address the issue. IPEN supports ending the Stockholm Convention recycling exemption because no convincing arguments for continuing it have been presented in the secretariat's review. In fact, the review confirms the flow of PentaBDE and OctaBDE into consumer products and notes the availability of techniques for separating materials containing brominated flame retardants. Toxic substances found in e-waste should not be recycled into consumer products. Ending the Stockholm Convention recycling exemption would reduce wider human and environmental contamination and help preserve the credibility of recycling.

CONCLUSION

Recycling of plastics containing toxic flame retardant chemicals found in electronic waste results in contamination of new plastic children's products. This extends human and environmental exposure and undermines the credibility of recycling. Toxic recycling and POPs wastes have significant impacts in developing and transition countries. There is now compelling evidence that environmental pollution is a major cause of death and illness in low and middle income countries. These countries are least able to manage or mitigate such threats because of their lack of capacity and sparse financial resources. In many countries, ending the Stockholm Convention recycling exemption and applying strict LPCLs for POPs contained in e-waste and other POPs will be the only global regulatory tool that can be used to prevent import and export of these contaminated products and wastes.

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ANNEX 1: FLAME RETARDANTS IN CHILDREN'S PRODUCTS

TABLE 1: RANGE OF CONCENTRATION (PPM) OF PBDEs IN RUBIK'S CUBES PER COUNTRY

Purchased in	Number of samples	OctaBDE	DecaBDE	HBCD
Argentina	3	0 - 342	0 - 359	0 - 1586
Bangladesh	2	27 - 41	33 - 96	1 - 5
Belarus	2	3 - 5	134 - 153	NA
Brazil	2	1 - 5	1 - 6	0
Canada	4	9 - 280	20 - 297	1 - 20
China	6	3 - 58	2 - 36	0/NA
Czech Republic	6	0 - 75	2 - 96	0 - 42
Germany	2	1	3 - 4	0
Hungary	2	0 - 6	0 - 58	0/NA
India	6	0 - 336	0 - 516	0 - 78
Indonesia	5	0 - 52	0 - 63	0 - 541
Japan	4	2 - 17	1 - 17	0
Kenya	3	15 - 226	18 - 171	0 - 1280
Mexico	5	20 - 178	17 - 152	0 - 2
Nepal	3	17 - 58	19 - 234	0 - 1
Nigeria	14	18 - 1174	25 - 672	0 - 9
Philippines	4	2 - 108	5 - 293	0 - 13
Poland	4	0 - 51	0 - 79	0
Russia	3	1 - 362	0 - 217	2 - 691
Serbia	3	13 - 57	36 - 47	NA
Slovakia	1	26	98	0
South Africa	3	57 - 509	98 - 281	1 - 60
Sri Lanka	2	46 - 48	44 - 131	0 - 1
Sweden	1	0	0	0
Thailand	2	25 - 48	21 - 23	0 - 5
United Kingdom	3	36 - 210	10 - 400	0 - 5

NA = not analyzed

TABLE 2: CONCENTRATION (PPM) OF PBDEs AND HBCD IN CHILDREN'S PRODUCTS FROM THE CZECH REPUBLIC AND THE NETHERLANDS

Item	Purchased in	OctaBDE	DecaBDE	HBCD
Toy - robot	Czech Republic	0	1	0
Toy - finger skate-board	Czech Republic	95	121	0
Toy - gun	Czech Republic	82	117	375
Toy – car 1	Netherlands	89	145	21
Toy – car 2	Netherlands	4	8	0
Children painting brush	Czech Republic	35	23	2
Children hockey stick	Czech Republic	6	9	0
Thermo cup	Czech Republic	3	6	0
Hair clip 1	Czech Republic	19	18	1
Hair clip 2	Czech Republic	18	18	5
Headdress 1	Czech Republic	9	33	0
Headdress 2	Czech Republic	102	78	19
Headdress 3	Czech Republic	107	195	24
Headdress 4	Slovakia	7	17	0
Comb 1	Czech Republic	6	5	0
Comb 2	Slovakia	0	0	0

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