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# Flame Retardants in General Consumer and Children's Products

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For more information contact:

Hazardous Waste and Toxics Reduction Program
P.O. Box 47600
Olympia, WA 98504-7600

Phone: 360-407-6700

Washington State Department of Ecology: ecology.wa.gov

- Headquarters, Olympia: 360-407-6000
- Northwest Regional Office, Shoreline: 206-594-0000
- Southwest Regional Office, Olympia: 360-407-6300
- Central Regional Office, Yakima: 509-575-2490
- Eastern Regional Office, Spokane: 509-329-3400

# Flame Retardants in General Consumer and Children's Products

*by*

*Saskia van Bergen and Alex Stone*

Hazardous Waste and Toxics Reduction Program
Washington State Department of Ecology
Olympia, Washington 98504-7600

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# Table of Contents

## List of Tables



## List of Figures

# Abstract

In 2012-2013, the Washington State Department of Ecology (Ecology) assessed the presence of flame retardant chemicals such as polybrominated diphenyl ethers (PBDEs), in general consumer and children's products.

Ecology collected 169 products from 30 retailers in Washington State between August 2012 and August 2013. Product types included seat cushions, mattresses, upholstered furniture for children, electronics, clothing, and baby carriers. A total of 163 product components from 125 products were sent to a laboratory for analysis.

The majority of samples tested (94%) did not contain PBDEs above a reporting limit of 100 parts per million (ppm), which supports the conclusion that manufacturers have moved away from using PBDEs in products available to Washington State consumers. Alternative flame retardants are still being used. Numerous products were found to contain chlorinated phosphate flame retardants, in particular tris(1,3-dichloro-2-propyl) phosphate (TDCPP) but also tris(2-chloroethyl) phosphate (TCEP) and tris(1-chloro-2-propyl) phosphate (TDPP), and the non-halogenated phosphate triphenyl phosphate (TPP). The majority of these samples were foam and many were children's products.

A subset of samples were tested for TBBPA, HBCD, and a newer flame retardant mixture called Antiblaze® V6 (V6). All three flame retardants were found in some of the samples analyzed.

A number of samples were found to contain a flame retardant identified as a chemical of high concern to children (CHCC) above the reporting limit established in the Children's Safe Product Act (CSPA). Ecology will review the data and determine if the manufacturer is in compliance with the CSPA reporting requirements.

# Introduction

## PBDEs and related compounds

Polybrominated diphenyl ethers (PBDEs) are a class of persistent, bioaccumulative and toxic (PBT) compounds that historically were used as flame retardants in a wide range of consumer products. In 2001, the total PBDE volume worldwide was estimated at over 67,000 metric tons. There were three different formulations of PBDEs used commercially in products, referred to as penta-BDE, octa-BDE, and deca-BDE. Each was used primarily in different applications. Penta-BDE was used in low density polyurethane foam in products such as furniture. Octa-BDE was used in certain electronic applications such as housings for fax and answering machines, automobile trim, telephone handsets, and kitchen appliance casings. For deca-BDE, the largest use was in electronic enclosures, particularly in computers and televisions (Ecology, 2006). One of the drivers of flame retardants in furniture is the California Standard Technical Bulletin 117, which is a state flammability standard for upholstered furniture.

PBDEs are not chemically bonded to the matrices of the materials. They can escape from their matrix through release to the air and accumulate in dust (Stapleton, 2008).

Studies indicate that PBDEs are ubiquitous throughout the natural environment, in air, soil, and sediments, and are building up in the food chain. PBDEs were detected in migrant Chinook salmon tissue and their stomach contents from four sites in Puget Sound. Other studies have demonstrated thyroid effects on adult fathead minnows and increased risk of disease in juvenile Chinook salmon. There is evidence of bioaccumulation of PBDEs in marine mammals at high concentrations in blubber, including in Puget Sound killer whales. PBDE levels have also been observed to be increasing in orcas resident in the Puget Sound Basin (Ecology, 2006). In conjunction with PBDE concentrations, concerns have been raised about the '*…increasing evidence of effects on reproductive health, the immune system, and development in exposed mammals*.' (Ross, 2006)

Manufacturers of penta-BDE and octa-BDE voluntarily agreed to stop production at the end of 2004 (Ecology, 2006). In 2009, the U.S. Environmental Protection Agency (EPA) announced another voluntary agreement to '*...end production, importation and sales of decaBDE for most uses in the United States by December 31, 2012*' (EPA, 2010). Companies have found alternatives for most PBDE uses.

In addition to the voluntary efforts undertaken by EPA, several states have banned the use of PBDEs in products sold within their state. In 2007, the Washington State Legislature passed legislation (Chapter 70.76 RCW[1]) banning the use of the penta- and octa-BDE mixtures, banning the use of deca-BDE in one application (mattresses) and providing the possibility of further bans on deca-BDE use if a safer alternative could be identified (Washington, 2007). Ecology and the Washington State Department of Health (DOH) conducted an alternatives assessment to determine if safer alternatives to deca-BDE existed for two additional applications: electronic enclosures (primarily computers and televisions) and residential upholstered furniture. As a result of this assessment, a safer alternative, resorcinol diphenyl phosphate

[1] http://apps.leg.wa.gov/RCW/default.aspx?cite=70.76

(RDP), was identified in 2009 for electronic enclosures. For upholstered residential furniture, the recommendation was to redesign the product to maintain fire safety without the use of chemical flame retardants. As of January 1, 2011, the deca-BDE ban was extended in Washington State to include these two applications (Ecology, 2009).

Deca-BDE was also identified by Ecology as a chemical of high concern to children (CHCC). In 2008, the Washington State Legislature passed the Children's Safe Product Act (Chapter 70.240 RCW[2]) that requires Ecology to identify chemicals that are both toxic and have a potential exposure pathway to children (Washington, 2008). As directed by this legislation, Ecology published a list of 66 CHCCs. Deca-BDE was one of the 66 (WAC 173-334-130[3]). Deca-BDE was placed on this list because of its carcinogenic potential, the tendency of deca-BDE to degrade to more toxic forms of PBDEs such as those found in the penta- and octa-BDE mixtures and children's potential exposure from its wide use as a flame retardant (DOH, 2010). Any manufacturer that uses deca-BDE in children's products sold in Washington State must report the use to Ecology (Ecology, 2011a).

With the banning of PBDEs, manufacturers have switched to a number of alternatives. Brominated alternatives include 2-ethylhexyl 2,3,4,5-tetrabromobenzoate (TBB), (2-ethylhexyl)tetrabromophthalate (TBPH), the polybrominated diphenyl ethanes (PBDP-ethanes), Hexabromocyclododecane (HBCD) and Tetrabromobisphenol-A (TBBPA). Concerns about their toxicological impacts have been raised given similarity to the PBDE formulations. In addition to being CHCCs, HBCD, and TBBPA are also listed as persistent, bioaccumulative toxins (PBTs) by rules adopted in 2006 (WAC 173-303[4]).

## Chlorinated phosphate flame retardants

In addition to deca-BDE, HBDC and TBBPA mentioned above, a chlorinated phosphate flame retardant, tris(2-chloroethyl) phosphate (TCEP), was also identified as a CHCC. Recently, a related compound, tris(1,3-dichloro-2-propyl) phosphate (TDCPP), was identified by the California Environmental Protection Agency as a chemical known to cause cancer and placed on the Proposition 65 list of toxic chemicals (Cal EPA, 2011). It was added to Ecology's CHCC list in 2013 through agency rulemaking. TDCPP has been commonly used as a flame retardant in foam, both in baby products and couches in the United States (Stapleton 2011, 2012). TCEP has also been associated with a newer flame retardant mixture called Antiblaze® V6 (V6), which reports the presence of TCEP as a 4.5-7.5% impurity (EU 2007).

A third flame retardant compound in this class, tris(1-chloro-2-propyl) phosphate (TCPP) has also generated some concern. The Organization of Economic and Cooperative Development (OECD) has indicated that TCPP is harmful to aquatic organisms (OECD, 2012). Given the similarity of this compound to TCEP and TDCPP, concerns have arisen about its widespread use. Like TCEP, TCPP has been associated with a previously uncharacterized flame retardant "U-OPFR" (Stapleton 2011).

[2] http://apps.leg.wa.gov/rcw/default.aspx?cite=70.240&full=true
[3] https://apps.leg.wa.gov/WAC/default.aspx?cite=173-334-130
[4] http://apps.leg.wa.gov/WAC/default.aspx?cite=173-333&full=true

Chlorinated phosphates including TCEP have been found in a number of environmental media, such as effluent from sewage treatment plants, precipitation (rain, snow, and glacial ice), and surface waters, primarily in Europe (EU, 2009).

TCEP and TCPP are slightly toxic to aquatic organisms at all trophic levels and TDCPP is moderately toxic to fish. All three compounds are slightly toxic to terrestrial species and aquatic green algae, and are non-toxic to sewage bacteria (NICNAS, 2001). Organophosphates including TCEP and TDCP have also been found in fish (perch and carp) in a limited study in Sweden (Marklund, 2005).

## Non-halogenated phosphate flame retardants

As mentioned previously, Ecology identified RDP as a safer alternative to deca-BDE, especially in the computer and television industry (Ecology, 2009). Other non-halogenated flame retardants were also reviewed in the same report. One of the flame retardants evaluated as an alternative, triphenyl phosphate (TPP), was eliminated due to its high environmental toxicity (Ecology, 2009). Data is lacking on whether these alternative chemicals are being widely used and if concerns about TPP warrant further evaluation.

TPP has been found in:

- Thirty-three dust samples tested in a study in Belgium (Van den Eede, 2011).
- Ninety-eight percent of 50 house dust samples tested in a U.S. study (Stapleton, 2009).
- Fish in a Swedish study of lakes and coastal regions (Sundkvist, 2010).
- Almost half of the fish sampled from Manila Bay in the Philippines (Kim, 2011).
- Reclaimed wastewater (Loraine, 2006).
- The blubber of six bottlenose dolphins from the Gulf of Mexico (Kuehl, 1995).

## Flame retardants in products

Recent studies have shown that many of the above flame retardants are found in products and with the phase-out of PBDEs, a more varied group of flame retardants is being used. Stapleton et al. studied polyurethane foam used in baby products and identified flame retardants in a wide range of products including car seats, changing table pads, sleep positioners, portable mattresses, nursing pillows, baby carriers, high chairs, and infant bath mat/slings (Stapleton, 2011). The most common flame retardant used was TDCPP, followed by the mixture Firemaster® 550 (FM 550), which contains multiple chemicals including TBB, TBPH, and TPP.

Chlorinated organophosphate flame retardants were the most common class found including TCEP, TCPP, V6, and "U-OPFR" in addition to TDCPP. Penta-BDE was found in a few of the products with TPP but the authors cautioned these were likely older products manufactured before specific bans were implemented. TPP was also found in one non-halogenated mixture sold commercially as AC073. Excluding demonstrated increase in the number of non-halogenated mixtures, Stapleton et al. found similar results in a study testing couch samples. Penta-BDE was successfully phased-out in the products tested after 2005 (Stapleton, 2012).

The concentration of flame retardants in house dust is widely used to monitor the presence of flame retardants in consumer products. Because many household products contain flame retardants that can be released and accumulated in house dust, dust has become a common sampling media. This connection was investigated and shown to have a high correlation between the amount and type of consumer products and the amount of PBDEs found in house dust (Allen, 2008). Alternative and new flame retardants like HBCD, TBB, TBPH, TCEP, TDCPP, TCPP, V6, and decabromodiphenyl ethane (deca-BDP-ethane) have been detected in house dust indicating that increasing numbers and different types of flame retardant are now used (Stapleton, 2008, 2009, Fang 2013).

During creation of the CHCC list, Ecology reviewed several sources of data on chemicals in products. Studies conducted by the Danish Environmental Protection Agency and similar bodies of the Dutch Government were particularly useful. In both instances, the organizations purchased products and evaluated them for a wide range of chemicals. This information was used to identify potential sources of exposure to children. Many of the flame retardants in these studies were found in general consumer and children's products. For example, TCEP was found in electronics, perfume in toys and children's articles, and plastic toys. TPP was found in electronics, baby products, and plastic toys. Penta-, octa- and deca-BDE were all found in electronics while deca-BDE was also found in indoor air sampling from various consumer products (Stone, 2010).

# Goals and Purpose

The objectives of this project were to evaluate presence of flame retardant chemicals such as PBDEs, in general consumer and children's products and to:

- Determine compliance with Washington State's ban on the PBDE class of flame retardants (RCW 70.76)
- Evaluate the level of substitute flame retardants in various consumer products.
- Verify compliance with Washington's Children's Safe Product Act (CSPA) reporting requirements for flame retardants on the CHCC list (RCW 70.240).

# Methods

The design and methods for this study are described in detail in the Quality Assurance Project Plan or QAPP (Ecology, 2012).

Early in 2013 through the CSPA reporting requirements, Ecology was notified that a product sampled for this study contained TBBPA, another flame retardant on the CHCC list, that was not part of the original group of analytes selected for analysis. As part of the effort to determine compliance and assess levels of all pertinent flame retardants, this project was extended to include additional analyses of a subsample of the products. These analyses included three additional flame retardants and the re-analysis of the chlorinated phosphate and triphenyl phosphate flame retardant compounds already analyzed by

Ecology's Manchester Environmental Laboratory (MEL). These re-analyses were done to confirm the ability to measure the original analytes. The design and methods for this study are described in a QAPP Addendum (Ecology, 2013).

## Sample selection

Products were purchased between August 2012 and August 2013 from local stores in the south Puget Sound area and online retailers. A total of 169 individual products were collected. Products that historically contained flame retardants were targeted for analysis. Table 1 shows the number of samples in each segment identified from the Global Product Classification Standard.

**Table 1: Number and types of products collected for the 2012-2013 Study.**

| Segment | # of products | % of Products collected |
|---|---|---|
| Household/Office Furniture/Furnishings | 31 | 18.3 |
| Baby Care | 18 | 10.7 |
| Home Appliances | 17 | 10.1 |
| Clothing | 19 | 11.2 |
| Toys/Games | 12 | 7.1 |
| Electrical Supplies | 9 | 5.3 |
| Building Products | 9 | 5.3 |
| Communications | 8 | 4.7 |
| Computing | 8 | 4.7 |
| Camping | 7 | 4.1 |
| Storage/Haulage Containers | 5 | 3.0 |
| Audio Visual/Photography | 5 | 3.0 |
| Beauty/Personal Care/Hygiene | 4 | 2.4 |
| Cleaning/Hygiene Products | 3 | 1.8 |
| Automotive | 3 | 1.8 |
| Fuels | 2 | 1.2 |
| Home/Business Safety/Security/Surveillance | 2 | 1.2 |
| Lawn/Garden Supplies | 2 | 1.2 |
| Tobacco/Smoking Accessories | 2 | 1.2 |
| Household/Office Furniture | 1 | 0.6 |
| Stationery/Office Machinery/Occasion Supplies | 1 | 0.6 |
| Pet Care | 1 | 0.6 |
| **Total Products** | **169** | |

## Sample processing and screening

Products were processed at Ecology headquarters where each was photographed and assigned a unique identification number. Product information such as brand, country of manufacture, manufacturer, distributor, or importer was recorded.

Products were deconstructed into individual components and screened using X-ray fluorescence (XRF). XRF is a quick, non-destructive method for obtaining the elemental composition of products. Components were defined as individual pieces or parts of the product containing different colors, functions, and/or material. A total of 385 different components from 169 products were screened for bromine with a scan time of 120 seconds using a Niton XL3t XRF analyzer. Chlorine was not effectively screened using XRF due to instrument settings. All samples were measured in Niton's TestAll® or Plastics Non PVC mode. Details of the sample preparation and XRF screening are described in the *Sample Processing Standard Operating Procedure*.[5] Chain-of-custody was maintained and documented throughout the process.

A total of 163 component samples from 125 products were sent to MEL for analysis. Fabric, stuffing, and foam samples were manually cut into small pieces. Plastic samples and some foam samples were frozen and milled in a cryogenic chamber. Plastic samples that contained metal, for example motherboards, were milled and metal removed. The components, type of products, and material identification (foam, plastic, etc.) were identified in the chain of custody (COC) sent to the laboratory (Appendix 1). General categories of the products sent to MEL and distributions are shown in Figure 1. Forty percent of the products were

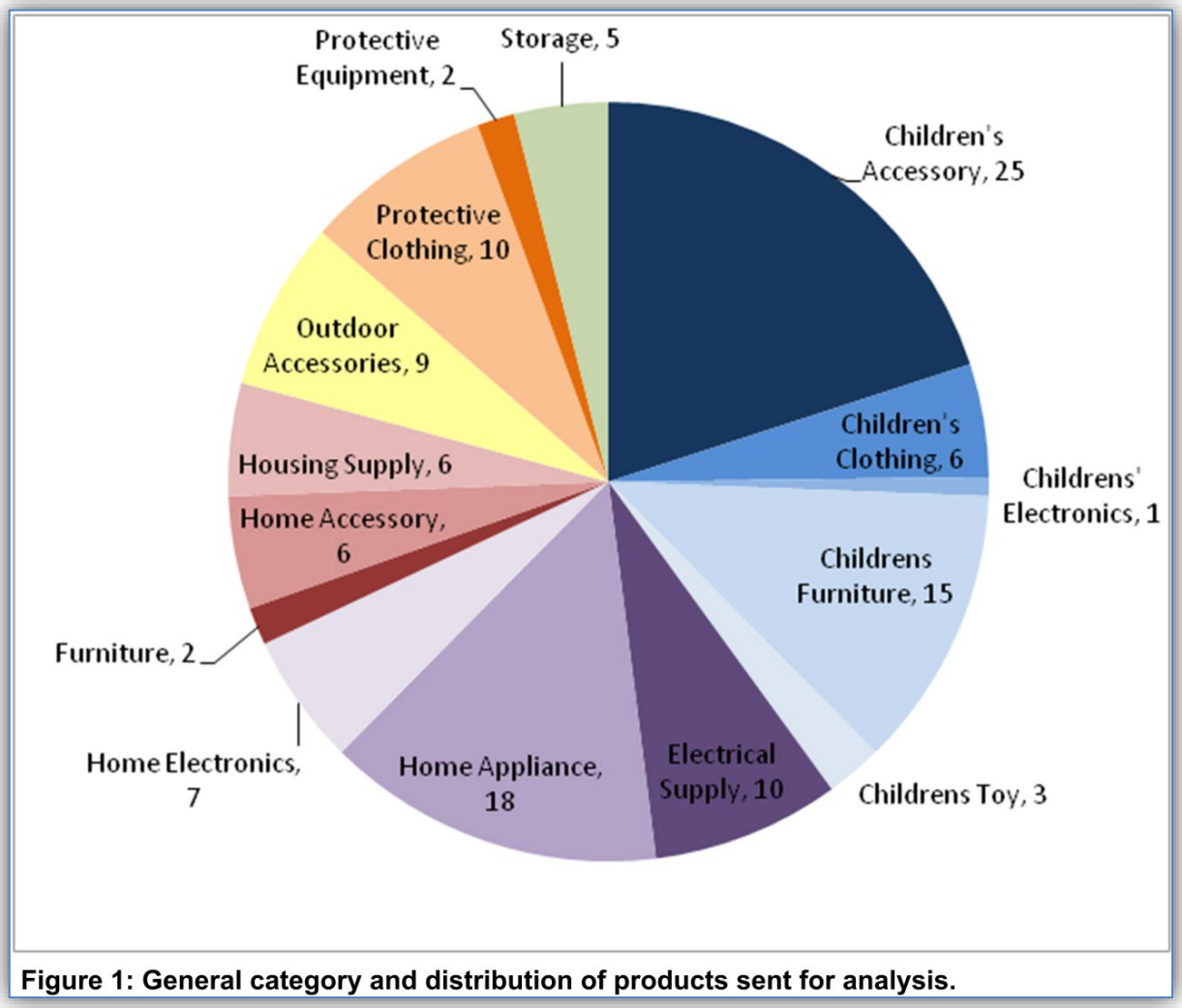


**Figure 1: General category and distribution of products sent for analysis.**

[5] https://fortress.wa.gov/ecy/publications/SummaryPages/1404013.html

targeted towards children including baby activity gyms, car seats, changing mats, pajamas, children's chairs, and stuffed animals. Seventy-two (44.2 %) of these samples were plastic, 42 (25.8 %) were foam, 33 (20.2 %) were fabric, 13 were stuffing (8.0%), one (0.6%) was fiberglass, one (0.6%) was Styrofoam, and one (0.6 %) was a solution.

From these 163 components, a subsample of 67 components from 61 products was sent to a second laboratory (ALS Environmental or ALS) to be analyzed for three additional analytes. The chlorinated and non-halogenated phosphates were re-analyzed to further validate MEL's analytical results. The bolded samples listed in Appendix 1 were sent to the second laboratory. The samples were chosen based primarily on bromine XRF screening results and preliminary data from MEL. Secondarily, a sample was sent if it had a California Standard Technical Bulletin 117 label (a state flammability standard for upholstered furniture) as the label indicates that a flame retardant is very likely present (Stapleton 2012). The distribution of products is displayed in Figure 2.

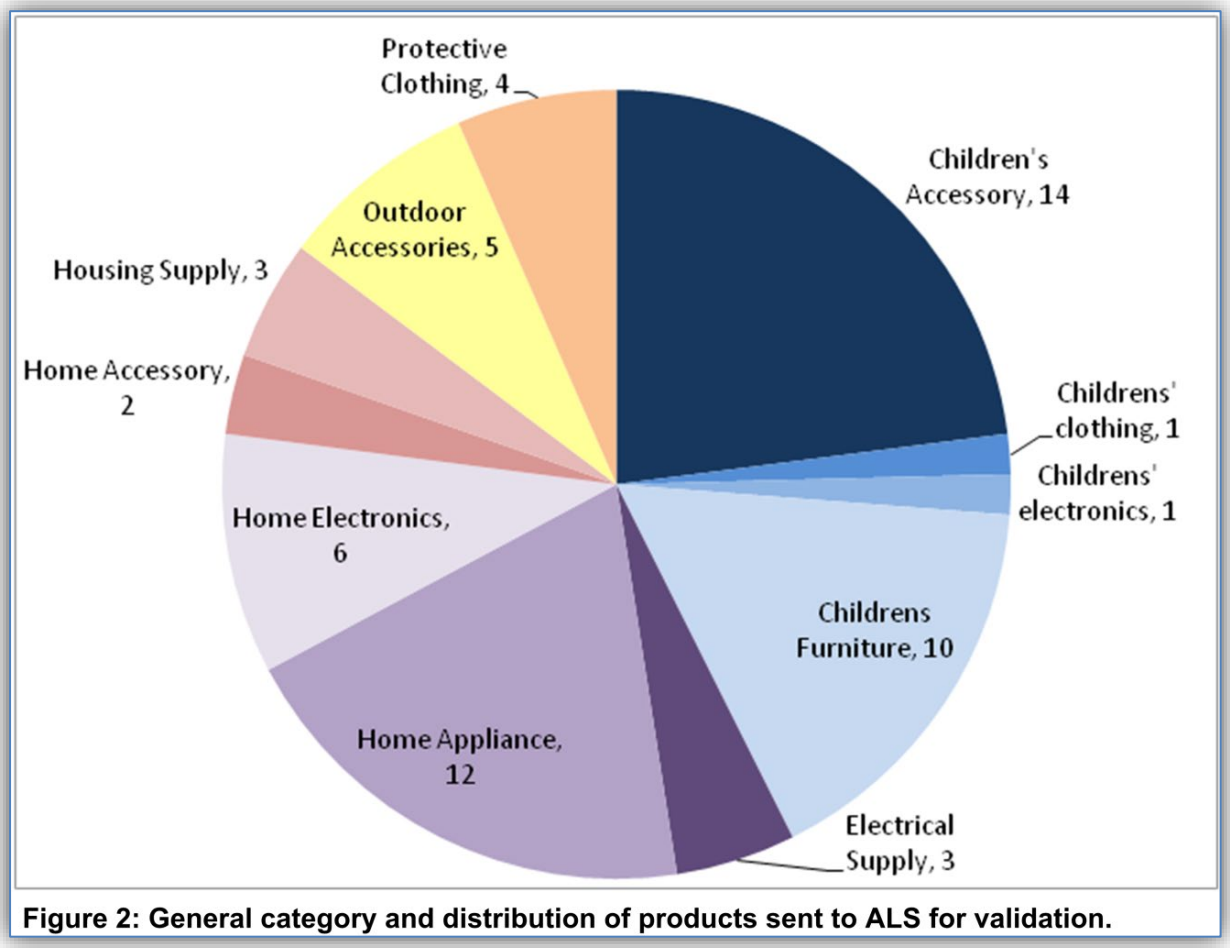


**Figure 2: General category and distribution of products sent to ALS for validation.**

## Laboratory procedures

### Cryomilling/Milling

Plastic and some foam samples selected for laboratory analysis were sent to ALS for cryomilling prior to analysis. Samples that could be cryomilled were done following ALS' Standard Operating Procedure for pulverizing samples employing a freezer/mill (EXT-GRIND). Samples were made brittle using cryogenic temperatures and then milled in an enclosed capsule by magnetically shaking the capsule back and forth. After cryomilling, samples consisted of homogenous particles.

## Flame Retardant Analysis

MEL extracted the flame retardant compounds listed in Table 2 in all samples following the Environmental Protection Agency's (EPA's) extraction Method 3546 (MEL Standard Operating Procedure (SOP) 730122) and analyzed using gas chromatography-mass spectrometry (GC/MS) following a modified EPA analytical Method 8270D (MEL SOP 730123). RDP (CAS #115-86-6) was included in the QAPP but was not analyzed due to lack of pure standard material.

**Table 2. Analytes of interest**

### PBDEs

| Analytes | CAS Number |
|---|---|
| PentaBDE formulation: | |
| PBDE 47 | 5436-43-1 |
| PBDE 49 | 243982-82-8 |
| PBDE-66 | 189084-61-5 |
| PBDE-71 | no CAS available |
| PBDE-99 | 60348-60-9 |
| PBDE-100 | 189084-64-8 |
| PBDE-138 | 182677-30-1 |
| OctaBDE formulation: | |
| PBDE 153 | 68631-49-2 |
| PBDE-154 | 207122-15-4 |
| PBDE-183 | 207122-16-5 |
| PBDE-184 | 189084-68-2 |
| PBDE-191 | no CAS available |
| Decabromodiphenyl ether (PBDE 209) | 1163-19-5 |
| Decabromodiphenyl ethane (deca-BDP-ethane) | 84852-53-9 |

**Chlorinated phosphates**

| Analytes | CAS Number |
|---|---|
| TCEP | 115-96-8 |
| TCPP | 13674-84-5 |
| TDCPP | 13674-87-8 |

**Non-halogenated phosphates**

| Analytes | CAS Number |
|---|---|
| TPP | 125997-21-9 |

Approximately 0.20 grams of sample were extracted via microwave-assisted extraction using a 70:30 acetone:hexane solution. After extraction, samples were concentrated, solvent exchanged into isooctane, and diluted. Samples were spiked with surrogates and an internal standard.

A subset of the initial samples was analyzed for the chlorinated and non-halogenated phosphates listed in Table 2 and the additional analytes listed in Table 3. ALS extracted these flame retardant compounds using EPA extraction Method 3540C. The extracts were analyzed using two methods:

1. Gas chromatography-mass spectrometry (GC/MS) following a modified EPA Method 8270D for the analytes in Table 2.

2. Liquid chromatography-mass spectrometry/ mass spectrometry (LC/MS/MS) following a modified EPA Method 1694 for the analytes in Table 3.

**Table 3: Additional analytes of interest**

| Analytes | CAS Number |
|---|---|
| V6 | 38051-10-4 |
| HBCD | 3194-55-6<br>25637-99-4 |
| TBBPA | 79-94-7 |

Approximately 0.20 grams of sample was extracted via Soxhlet extraction using a 70:30 acetone:hexane solution. After extraction, samples were concentrated and split. The extract for LC/MS/MS was solvent exchanged into acetonitrile. Samples were spiked with surrogate and internal standard solutions.

Standards were purchased as pure neat material with the exception of V6, which was purchased as a technical grade material and purified following the procedure described in Fang et al. 2013.

# Data Quality

## XRF

XRF performance was assessed at the beginning of a batch of samples with a system test and the results of a plastic reference sample run at the beginning and end of a batch. The plastic standard did not include the elements bromine and chlorine.

## Laboratory

MEL conducted a data quality review of their data packages and the sub-contracted laboratory data packages. Case narratives describing the quality of laboratory data, including instrument calibration, and quality control tests, are available upon request. Quality control tests for each batch analyzed consisted of a method blank, laboratory control samples (LCS), matrix spikes/matrix spike duplicates, and if enough sample was available, a laboratory duplicate. The reporting limit of 100 ppm was selected for the analytes of interest.

Measurement quality objective (MQO) targets outlined in the QAPP and Addendum differed from those reported from the lab as there was minimal history on the methods and the initial target criteria were too restrictive. The lab defined changes to the criteria and the Project Manager agreed. The actual acceptance criteria are shown in Table 4 and reviewed below.

**Table 4: MQOs for laboratory analyses**

| Analyte | Lab Control Samples (recovery) | Matrix[+] Spikes (recovery) | Duplicates[+] (RPD)[++] | Method Blanks (ppm)[+++] | Surrogate Recovery (recovery) |
|---|---|---|---|---|---|
| PBDEs | 50-150% | 50-150% | ± 40% | <100 for all except <500 for 209 | 50-150% |
| Deca-BDP-ethane | 50-150% | 50-150% | ± 40% | < 100 | 50-150% |
| Chlorinated phosphates | 50-150% | 50-150% | ± 40% | < 100 | 50-150% |
| Non-halogenated phosphates | 50-150% | 50-150% | ± 40% | < 100 | 50-150% |
| V6 | 60-140% | 60-140% | ± 50% | < 100 | 50-150% |
| HBCD | 60-140% | 60-140% | ± 50% | < 100 | 50-150% |
| TBBPA | 60-140% | 60-140% | ± 50% | < 100 | 50-150% |

[+] Matrix spike duplicates and split duplicates

[++] RPD = Relative Percent Difference

[+++] ppm = parts per million

## PBDEs and deca-BDP-ethane

Data for the sample analyses were generally within the MQO targets outlined in Table 4. All method blanks were below reporting limits. MEL encountered solubility problems with deca-BDP-ethane analytical standards; therefore, all deca-BDP-ethane results were qualified as estimates. PBDEs and deca-BDP-ethane were not spiked into the Matrix Spikes due to cost considerations.

Instances where MQOs were not achieved or standard laboratory procedures were outside of acceptance limits included:

- Several calibration checks (continuous) for deca-BDP-ethane were outside of acceptance limits resulting in qualifying the data as estimates.
- Several surrogate recoveries were outside of the MQO limits set resulting in qualifying the brominated data as estimates.
- Laboratory Control Sample (LCS) recoveries were low in one BDE-209 batch resulting in a UJ flag.

Additionally, instrument calibration procedures were outside of laboratory-identified targets in several instances. This, along with the MQO violations above, caused some results to be qualified as estimates.

## Chlorinated phosphates (from MEL)

Data for the sample analyses were generally within the MQO targets outlined in Table 4. All method blanks were below reporting limits. Instances where MQOs were not achieved or standard laboratory procedures were outside of acceptance limits included:

- Several calibration checks (initial) for TCPP and TDCPP were outside of acceptance limits resulting in qualifying the data as estimates.

- Several calibration checks (continuous) for TCPP and TCEP were outside of acceptance limits resulting in qualifying the data as estimates.
- An LCS for TCPP was outside acceptance limits resulting in qualifying the data as estimates.
- Recoveries of one matrix spike were not calculated for TCPP and TDCPP due to high concentrations in the native sample.
- Recovery of one matrix spike was low for TCEP resulting in a UJ flag for the native sample.

## Non halogenated phosphates (from MEL)

Sample data were generally within the MQO targets outlined in Table 4. All method blanks were below reporting limits. One method blank tentatively identified TPP below the reporting limit but all samples with detects were greater than five times the amount found in the blank; therefore, no qualifiers were added. Instances where MQOs were not achieved or standard laboratory procedures were outside of acceptance limits included:

- Surrogate recoveries of TPP-d15 were outside of acceptance limits in some samples resulting in qualifying the TPP data as estimated.
- Recoveries of one matrix spike were not calculated for TPP due to high concentrations in the native sample.

## HBCD, V6, TBBPA

Sample data were within the MQO targets outlined in Table 4 with the exception of one matrix spike that had a high recovery of HBCD. All method blanks were below reporting limits.

## Chlorinated phosphates (from ALS)

Data for the sample analysis were generally within the MQO targets outlined in Table 4. All method blanks were below reporting limits. Instances where MQOs were not achieved or standard laboratory procedures were outside of acceptance limits included:

- One matrix spike recovery was not calculated as the native sample was inhomogeneous.
- TDCPP recoveries for one matrix spike were outside of acceptance limits resulting in the native sample being qualified as an estimate.
- One duplicate sample had TDCPP five times lower than the first sample, which resulted in qualifying both samples as estimates.

## Non halogenated phosphates (from ALS)

Sample analysis data were generally within the MQO targets outlined in Table 4 with the exception that surrogate recoveries of TPP-d15 were outside of acceptance limits in two samples resulting in qualifying the TPP data as UJ. All method blanks were below reporting limits.

# Results and Discussion

## XRF screening

Three hundred, eighty-five different components from 169 products were screened for bromine using an XRF analyzer. Chlorine was not effectively screened using XRF due to instrument settings.

Scanning 385 components using XRF produced:

- 207 samples with non-detects for bromine (<LOD)
- 110 samples with bromine levels less than 1,000 ppm
- 26 samples with bromine levels between 1,000 and 5,000 ppm
- 42 samples with bromine levels above 5,000 ppm (0.5%)

Of the samples greater than 1,000 ppm, 79.4% of them (54 samples) were sent to the laboratory. Most of these were plastic. Table 5 lists the matrix type of the samples sent to MEL above 1,000 ppm bromine.

**Table 5: Bromine XRF screening ranges and matrices sent to MEL greater than 1,000 ppm**

| Matrix | Bromine XRF Results 1,000–5,000 ppm | Bromine XRF Results greater than 5,000 ppm |
|---|---|---|
| Foam | 7 | 4 |
| Plastic | 7 | 29 |
| Fabric | 4 | 3 |

## Laboratory results from MEL

One hundred, sixty-nine component samples from 125 products were sent to MEL laboratory for analysis of the flame retardants identified in Table 2. Forty (23.7%) of these components from 36 (28.8 %) products had concentrations of one or more of the analytes (Table 2) above the method reporting limit. Individual concentrations ranged from the reporting limits to 84,000 ppm. A summary of the amount of analyte and matrix are listed in Table 6. Most of the samples with analytes in the percent level (>10,000 ppm) were foam samples. The remaining two were fabric.

**Table 6: Summary of matrix and analyte concentration measured in products**

| Matrix | Sum of analytes less than 1000 ppm | Sum of analytes 1,000–9,999 ppm | Sum of analytes greater than 10,000 ppm (greater than 1%) | Total samples above RL |
|---|---|---|---|---|
| Foam | 1 | 7 | 17 | 25 |
| Plastic | 7 | 3 | - | 10 |
| Fabric | 1 | 2 | 2 | 5 |

## Polybrominated diphenyl ethers and deca-BDP-ethane

Table 7 displays the components where the PBDEs and deca-BDP-ethane concentrations measured above the reporting limits. These analytes were detected in ten components from nine products. PBDEs were found in eight components of seven products and deca-BDP-ethane was found in six components of five products. The majority of the samples were very close to their reporting limits. Only three results, which are bolded in Table 7, were above 1,000 ppm. As mentioned previously, MEL encountered solubility problems with deca-PBD-ethane analytical standards; therefore, all deca-BDP-ethane results were qualified as estimates. One sample was from a children's product (product description is highlighted blue).

**Table 7. PBDE and ethane levels measured in products**

| Sample Name | Analyte | Result (ppm) | Matrix | Product Description |
|---|---|---|---|---|
| GR000-F01 | BDE-209 | **2,400** | Plastic | Plastic Pallet |
| OM003-F01 | BDE-183 | 190 | Plastic | Shredder |
| OM003-F01 | BDE-209 | **2,600** | Plastic | Shredder |
| OM003-F01 | Deca-BDP-ethane | 750 J | Plastic | Shredder |
| OM003-F02 | BDE-183 | 310 | Plastic | Shredder |
| OM003-F02 | BDE-209 | **1,800** | Plastic | Shredder |
| OM003-F02 | Deca-BDP-ethane | 1,000 J | Plastic | Shredder |
| LW002-F01 | BDE-047 | 150 | Foam | Carpet Padding |
| LW000-F01 | BDE-209 | 200 | Foam | Carpet Padding |
| LW000-F01 | BDE-047 | 150 | Foam | Carpet Padding |
| LW000-F01 | BDE-099 | 300 | Foam | Carpet Padding |
| LW001-F01 | BDE-209 | 140 | Foam | Carpet Padding |
| LW001-F01 | BDE-047 | 110 NJ | Foam | Carpet Padding |
| LW001-F01 | BDE-099 | 250 | Foam | Carpet Padding |
| WM066-F01 | Deca-BDP-ethane | 250 NJ | Plastic | Battery Charger |
| WM068-F03 | Deca-BDP-ethane | 470 J | Plastic | Foot Warming Pad |
| CT009-F03 | Deca-BDP-ethane | 350 NJ | Plastic | LED TV |
| BY002-F08 | Deca-BDP-ethane | 620 J | Plastic | Child's Tablet |

In Washington, penta-BDE and octa-BDE are prohibited in all products. Deca-BDE is prohibited in mattresses, residential upholstered furniture, and "electronic enclosures" for computer monitors and televisions. Ecology has issued guidance clarifying that it may take enforcement actions if PBDE levels exceed 1,000 ppm by weight in a restricted product. None of the PBDE levels found violated Washington law.

Flame retardants are typically used in the percent level. Levels near the reporting limit could be cross contamination during manufacture, flame retardant impurities, or flame retardants from recycled content. Concentrations lower than percent level could be part of a mixture. While 54 of these samples screened positive for bromine above 1,000 ppm using the XRF, only three samples contained

brominated analytes listed in Table 2 above 1,000 ppm. This suggests that there are additional brominated compounds in the samples.

Firemaster® 550 mixture (FM550) is one likely alternative to PBDEs. It contains two brominated compounds, 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB) and bis(2-ethylhexyl)-2,3,4,5-tetrabromophthalate (TBPH), and triphenylphosphate (TPP) in addition to several isopropylated triaryl phosphate isomers. FM550 has been found in children's products and couches (Stapleton 2011, 2012). Two additional alternatives are HBCD and TBBPA. A subset of samples from this study was evaluated for the latter two flame retardants and these results will be discussed in a later section.

## Chlorinated phosphates

Chlorinated phosphate flame retardants were detected in 27 components (21 foam, five fabric, and one plastic) from 24 products. Twenty-four of the components from 22 products contained individual flame retardants above 1,000 ppm. Of these 22 products, 14 are children's products. About half of the samples contained flame retardants at the percent level (above 10,000 ppm). Table 8 displays the list of samples where at least one chlorinated phosphate level measured above the reporting limit.

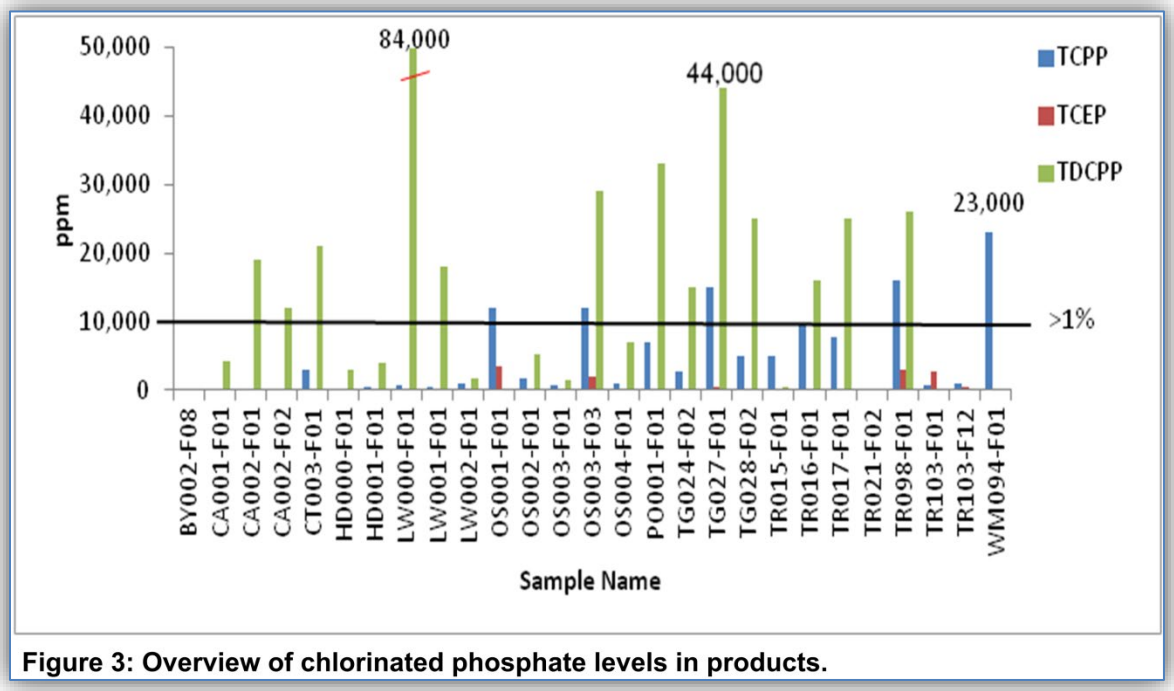


**Figure 3: Overview of chlorinated phosphate levels in products.**

In agreement with previous studies (Stapleton 2011, 2012), TDCPP was the most common chlorinated phosphate detected in foam. Twenty samples (17 foam and three fabric) contained TDCPP above 1,000 ppm. The fabric components came from tent products, which met the CPAI-84 Flammability Specification for Flame-resistant Materials Used in Camping Tentage, the U.S. tent flame retardant standard promulgated by the Industrial Fabrics Association International. Keller et al (2014) found similar levels in tent textiles.

Four children's products contained TCEP above 1,000 ppm. Seven samples from six children's products were above state Practical Quantitation Limit (PQL) of 100 ppm for reporting TCEP to Ecology as required by the CSPA. Five samples were foam while two were fabric. These values are bolded in red in Table 8. TCEP can be an impurity from another flame retardant known as V6, also found in foam. A subset of samples from this study was evaluated for V6. The results are discussed in a later section.

Thirteen products, all foam, contained TCPP above 1,000 ppm. Eleven samples were children's products. Many of these also contained a higher concentration of TDCPP. Similar to TCEP, TCPP can be an impurity in another flame retardant found in recent studies currently called 'unidentified chlorinated organophosphate flame retardant' (U-OPFR).

**Table 8: Chlorinated phosphate levels measured in products**

| Sample | Analyte: TDCPP (ppm) | Analyte: TCPP (ppm) | Analyte: TCEP (ppm) | Matrix | Product Description |
|---|---|---|---|---|---|
| TG027-F01 | **44,000 J** | **15,000 J** | **550 J** | Foam | Booster Seat |
| OS003-F03 | **29,000 J** | **12,000 J** | **2,100 J** | Foam | Child's Chair |
| TR098-F01 | **26,000** | **16,000 J** | **3,000** | Foam | Child's Chair |
| TG028-F02 | **25,000 J** | **4,900 J** | < 87 | Foam | Changing Pad |
| TR017-F01 | **25,000 J** | **7,700** | < 93 | Foam | Crib Wedge |
| TR016-F01 | **16,000 J** | **9,700** | < 92 | Foam | Portable Crib Pad |
| TG024-F02 | **15,000** | **2,800 J** | **270 J** | Foam | Changing Mat |
| OS004-F01 | **7,000 J** | 890 | < 98 | Foam | Child's Chair Accessory |
| OS002-F01 | **5,300** | **1,800 J** | < 97 | Foam | Child's Chair |
| OS003-F01 | **1,600** | 700 | 100 J | Foam | Child's Chair |
| TR015-F01 | 370 J | **5,000** | < 93 | Foam | Changing Pad |
| TR021-F02 | 270 | < 98 | < 98 | Foam | Pee protector |
| BY002-F08 | 250 J | < 92 | < 92 | Plastic | Child's Tablet |
| TR103-F12 | < 97 | 870 | **510 J** | Fabric | Baby Carrier |
| OS001-F01 | < 97 | **12,000** | **3,400 J** | Foam | Child's Chair |
| TR103-F01 | < 96 | 640 J | **2,700** | Fabric | Baby Carrier |
| WM094-F01 | < 96 | **23,000 J** | < 96 | Foam | Child's Chair |
| LW000-F01 | **84,000 J** | 690 | 120 | Foam | Carpet padding |
| PO001-F01 | **33,000 J** | **7,000 J** | < 98 | Foam | Seat Cushion |
| CT003-F01 | **21,000 J** | **3,000** | <96 | Foam | Chair Pad |
| CA002-F01 | **19,000 J** | < 100 | 160 | Fabric | Tent |
| LW001-F01 | **18,000 J** | 370 | < 97 | Foam | Carpet padding |
| CA002-F02 | **12,000 J** | < 98 | 130 | Fabric | Tent |
| CA001-F01 | **4,300** | ND | 180 | Fabric | Tent floor liner |
| HD001-F01 | **4,100 J** | 550 | < 94 | Foam | Carpet padding |
| HD000-F01 | **2,900 J** | 180 | < 96 | Foam | Carpet padding |
| LW002-F01 | **1,800 J** | 990 | 150 | Foam | Carpet padding |

*Blue highlighted results are children's products.*

## Non halogenated phosphates

Fifteen samples from 14 products contained TPP above the reporting limits (Table 9), where seven were above 1,000 ppm. TPP is used both as a plasticizer and as a flame retardant in halogenated and non-halogenated flame retardant mixtures (Stapleton 2009, 2012). The two non-halogenated mixtures found by Stapleton et al. contained TPP with either tris(4-(tert-butyl)phenyl) phosphate and several butylphenyl isomers or with several methyl- or dimethyl- phenyl phosphate isomers. One halogenated mixture containing both TPP and the halogenated compounds 2-ethylhexyl 2,3,4,5-tetrabromobenzoate (TBB) and (2-ethylhexyl)tetrabromophthalate (TBPH), is known as FM550. FM550 has frequently been found in children's foam products and furniture (Stapleton 2011, 2012).

Of the seven samples with TPP above 1,000 ppm, four had bromine levels above 10,000 ppm (one percent by weight) suggesting these products used halogenated mixtures. Three were children's furniture containing foam.

**Table 9: TPP levels measured in products**

| Sample | Analyte | Conc. (ppm) | Matrix | Product Description | Br > 1% (XRF) |
|---|---|---|---|---|---|
| AM009-F01 | TPP | **29,000 J** | Foam | Child's Chair | |
| TG031-F01 | TPP | **13,000 J** | Foam | Child's Chair | + |
| AM008-F01 | TPP | **10,000 J** | Foam | Child's Chair | + |
| PB000-F01 | TPP | **6,300** | Foam | Child's Chair | + |
| OM005-F08 | TPP | **21,000** | Plastic | LCD Monitor | + |
| WM066-F01 | TPP | **13,000** | Plastic | Battery Charger | |
| HD001-F01 | TPP | **2,700** | Foam | Carpet padding | |
| CT010-F05 | TPP | 920 | Plastic | Blue ray DVD player | |
| LW000-F01 | TPP | 700 | Foam | Carpet padding | |
| HD000-F01 | TPP | 610 | Foam | Carpet padding | |
| LW002-F01 | TPP | 560 | Foam | Carpet padding | |
| OM003-F01 | TPP | 440 | Plastic | Shredder | + |
| LW001-F01 | TPP | 400 | Foam | Carpet padding | |
| OM003-F02 | TPP | 290 | Plastic | Shredder | + |
| OM000-F02 | TPP | 210 | Plastic | LCD Monitor | |

*+ samples screened positive for > 1% bromine using XRF*

## Laboratory results from ALS

A subsample of Sixty-seven component samples from 61 products were sent to a second laboratory (ALS) to be analyzed for three additional analytes listed in Table 3, and the chlorinated and non-halogenated phosphates from Table 2 were re-analyzed to compare the results from the two laboratories.

### HBCD, V6, TBBPA

HBCD, V6, and TBBPA were detected in 14 samples from 14 products (Table 10). Nine were above 1,000 ppm.

**Table 10: HBCD, TBBPA, and V6 levels measured in products**

| Sample | Analyte | Conc. (ppm) | Matrix | Product Description |
|---|---|---|---|---|
| GR003-F01 | HBCD | **44,300** | Plastic | Protective Glove |
| WM095-F01 | HBCD | **563** | Styrofoam | Bean Bag Chair |
| WS002-F01 | TBBPA | **94,300** | Plastic | Car charger |
| WM068-F03 | TBBPA | **65,100** | Plastic | Heated mattress foot warming pad |
| OM003-F02 | TBBPA | **35,200** | Plastic | Shredder |
| OM000-F02 | TBBPA | **12,400** | Plastic | Battery Charger |
| BL005-F01 | TBBPA | 282 | Plastic | Hair Flat Iron |
| FM043-F01 | TBBPA | 196 | Plastic | Clothing Iron |
| TR103-F01 | V6 | **42,500** | Foam | Baby Carrier |
| OS001-F01 | V6 | **37,200** | Foam | Child's Chair |
| TR098-F01 | V6 | **16,200** | Foam | Child's Chair |
| CA002-F01 | V6 | **2,390** | Fabric | Tent |
| LW002-F01 | V6 | 201 | Foam | Carpet padding |
| LW000-F01 | V6 | 74.5 | Foam | Carpet padding |

HBCD was detected in a plastic and a Styrofoam component. One sample was above 1,000 ppm and the other, a child's bean bag chair, was above the CSPA criteria for reporting HBCD in children's products. This potential compliance value is bolded in red (Table 10).

V6 was detected in one fabric and five foam products. Four of these results were above 1,000 ppm. TCEP is an impurity in V6 and has been reported as 4.5-7.5 % of the V6 (EU, 2007). Three of these children's products were above the CSPA criteria for TCEP in children's products, which indicates that V6 was the source of TCEP.

TBBPA was detected in six plastic components in six products. Four of these were above 1,000 ppm. None of these were children's products.

## Chlorinated phosphates and non halogenated phosphates

Samples containing flame retardants above 1,000 ppm from ALS or MEL are listed in Appendix 2. Thirty-nine analytes were detected in 23 different products and the majority were foam components. Detection consistence between laboratories was excellent indicating that MEL and ALS were able to measure the analytes reliably. Only a qualitative comparison is possible as no reference standards in the appropriate matrices and only two labs were used.

The results (Figures 4-7) indicate ALS reported higher values than MEL in almost all samples. This would indicate that either ALS is biased high or MEL is biased low or both. Sample LW000-F01's TDCPP result was the only exception. This sample was a foam carpet padding made up of multiple colored foam. It is believed that the sample was not homogeneous and was the main cause for the variable results.

The accuracy of the results from the two labs is unknown as there are no reference standards for the analytes measured in the matrices tested. Some of the main factors that affect accuracy are:

- Extraction efficiency, which can be affected by extraction type, matrix, solvent used and extraction conditions.
- Analytical methods including surrogates and internal standards used, instrumentation and calibration method.

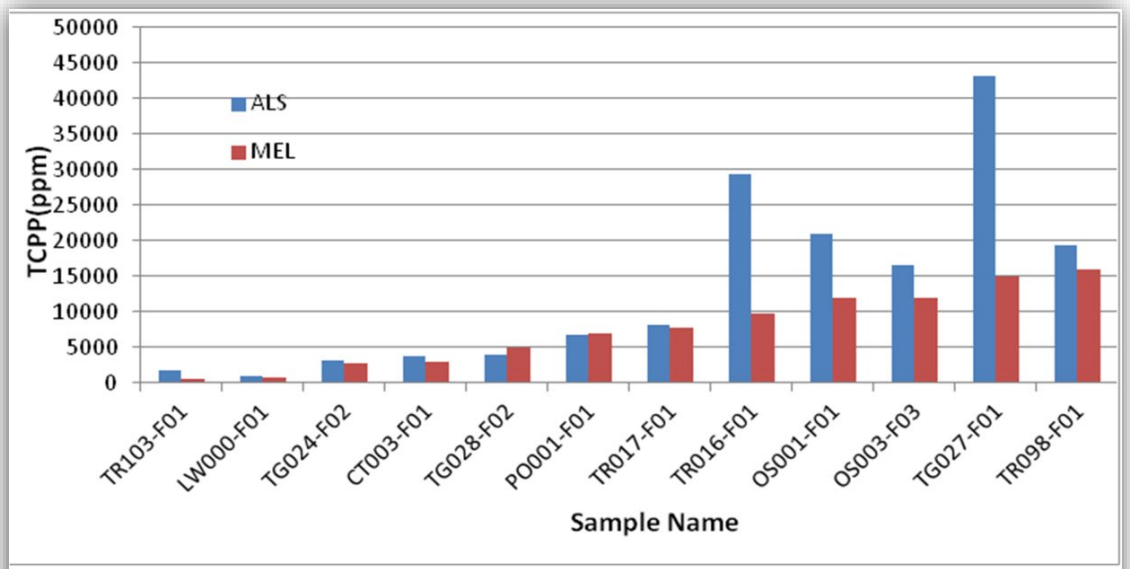


**Figure 4: Comparison of laboratory levels of TCPP in products.**

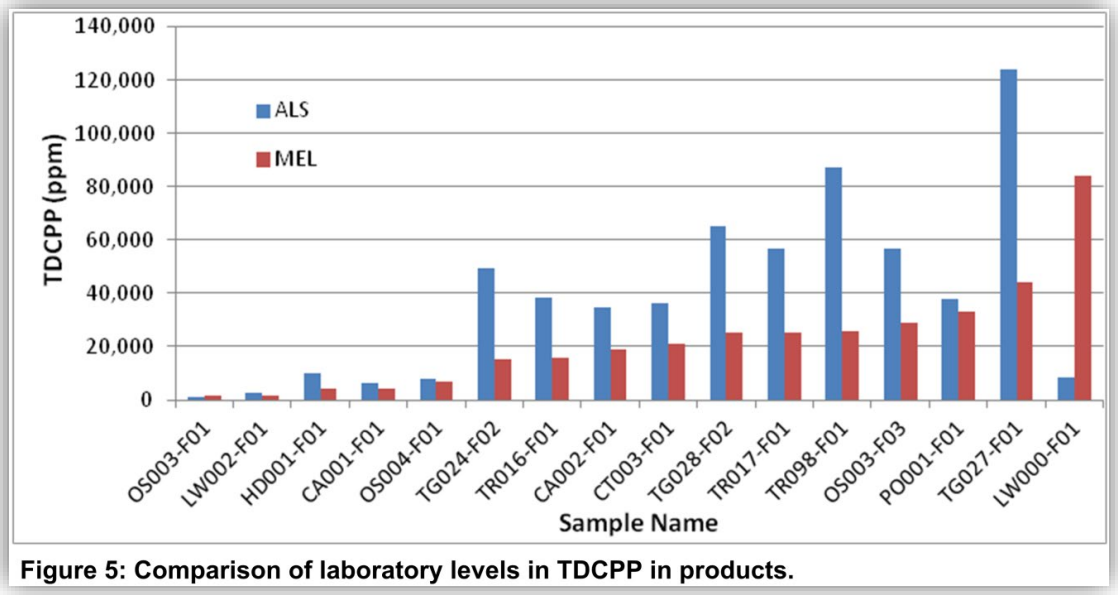


**Figure 5: Comparison of laboratory levels in TDCPP in products.**

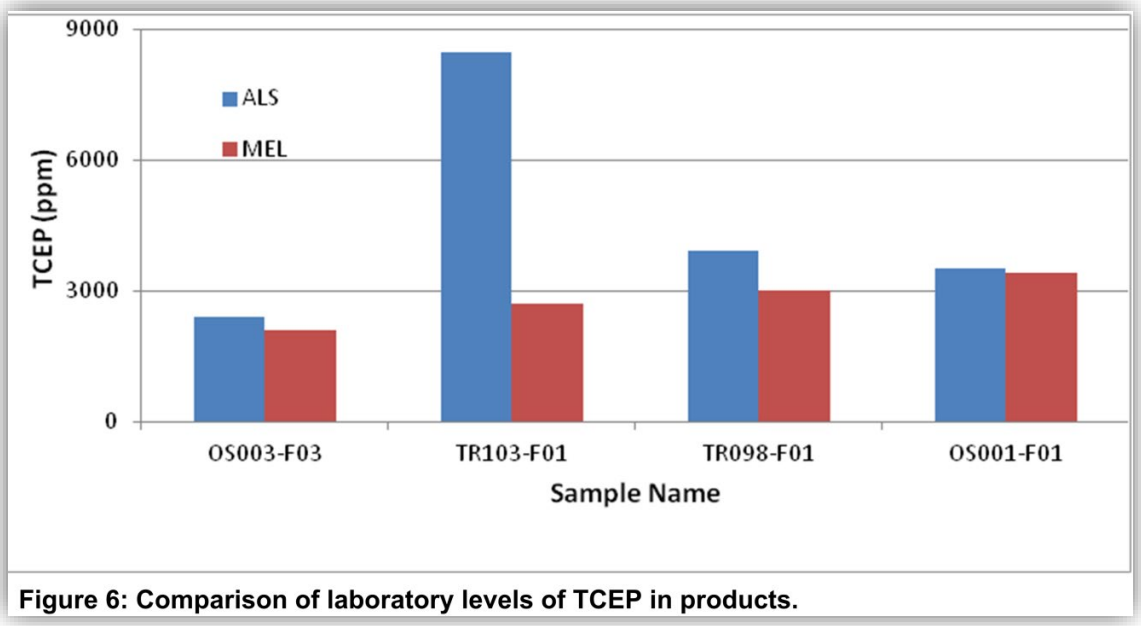


**Figure 6: Comparison of laboratory levels of TCEP in products.**

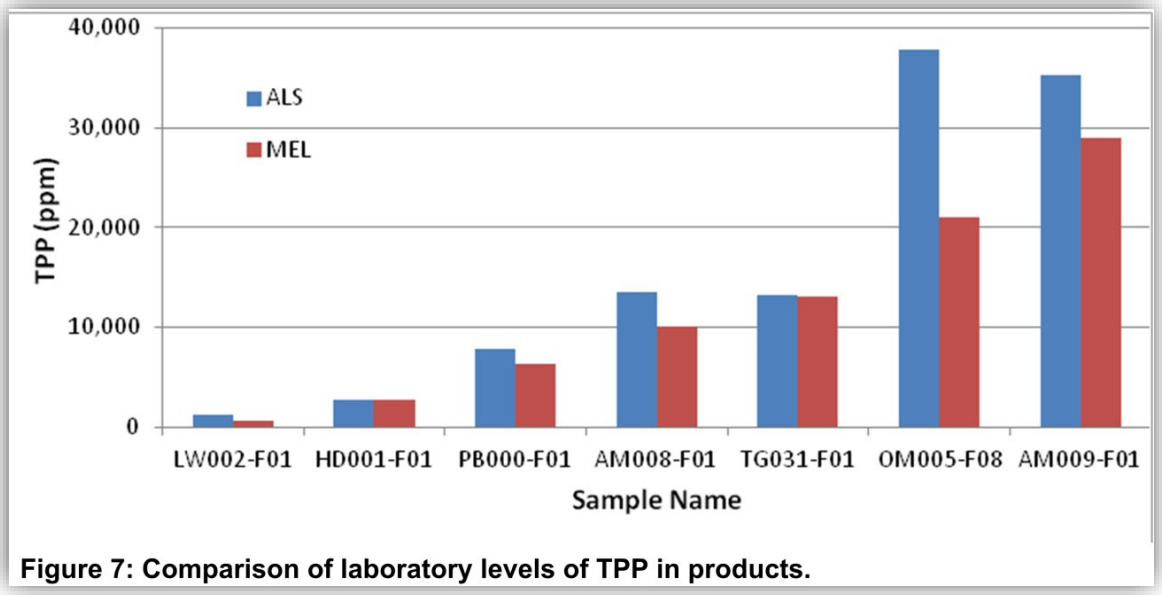


**Figure 7: Comparison of laboratory levels of TPP in products.**

# Summary

Results from this study support the following conclusions:

- Most of the samples did not contain PBDEs above the 100 ppm reporting limit. Only three of 163 product components tested contained PBDEs above 1,000 ppm. Manufacturers have largely moved away from using PBDEs and their products are compliant with Washington regulations.

- Numerous products were found to contain chlorinated phosphate flame retardants and particularly TDCPP. A majority of these samples were foam and many were children's products. Several products contained multiple flame retardants suggesting mixtures are being used.

- A few samples contained TPP. Most were foam but some were fabric. XRF results indicate that three of these samples also contained bromine indicating a halogenated flame retardant was likely used in the mixture. These samples were children's products.

- Products were found to contain HBCD and TBBPA. These flame retardants were mainly found in plastic samples. Until companies reported as required under the CSPA, Ecology did not have information to indicate these flame retardants were used in children's products.

- V6 is being used in several children's products. Most of the samples were foam but one was fabric. TCEP is an impurity in V6 and levels in these products were above the CSPA criteria for TCEP.

- TCEP was found in seven samples from six products at levels above the CSPA reporting criteria. HBCD was found in one product at levels above the CSPA reporting criteria.

- While foam was the matrix where most of the analytes were detected, plastic had the most frequent detects via XRF for bromine. This suggests flame retardants not assessed in this study are in use.

- Problems exist with the analysis of both deca-PBD-ethane and RDP because of the inability to obtain and create adequate standards.

- Aside from deca-PBDethane and RDP, flame retardants can be measured in products at levels necessary to determine compliance with Washington regulations.

# Recommendations

Based on findings of this study, the following recommendations are made:

- While not as effective as bromine, future sampling efforts for flame retardants should include a screening of chlorine using XRF. Reference standards should be purchased to ensure that the instrument is working within acceptable limits.

- Follow-up sampling and analysis should consider alternative analytes such as Firemaster® 550, commonly found in foam.

- Additional alternative brominated flame retardants should be assessed in plastics, as many plastic samples were found from screening analyses to contain bromine. For the majority of samples, however, the brominated alternatives were not identified.

- In order to assess TPP use, additional analytes commonly found in mixtures with TPP, such as Firemaster® 550 and tris(4-(tert-butyl)phenyl) phosphate should be measured.

- Children's products that meet the flammability requirements of CPAI-84 should be tested to understand what, if any, flame retardants are being used.

- Additional analysis of children's foam furniture should be performed. This group was most likely to have levels above the CSPA reporting criteria.

- Ecology should work with manufacturers and other interested parties to obtain pure standards for analysis.

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# Acronyms, Abbreviations, and Appendices

## Acronyms

| | |
|---|---|
| CHCC | Chemical of high concern to children |
| CSPA | Washington's Children's Safe Product Act |
| DOH | Washington State Department of Health |
| Ecology | Washington State Department of Ecology |
| EPA | U.S. Environmental Protection Agency |
| FDA | Food and Drug Administration |
| HBCD | Hexabromocyclododecane |
| FM550 | Firemaster® 550 |
| LCS | Laboratory control sample |
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| OECD | Organization of Economic and Cooperative Development |
| RCW | Revised Code of Washington |
| RDP | Resorcinol diphenyl phosphate |
| PBDEs | Polybrominated diphenyl ethers |
| PBD-ethanes | Polybrominated diphenyl ethanes |
| TBBPA | Tetrabromobisphenol-A |
| TCEP | Tris(2-chloroethyl) phosphate |
| TCPP | Tris(1-chloro-2-propyl) phosphate |
| TDCPP | Tris(1,3-dichloro-2-propyl) phosphate |
| TPP | Triphenyl phosphate |
| U-OPFR | Unidentified chlorinated organophosphate flame retardant |
| V6 | 2,2-bis(chloromethyl)-propane-1,3-diyltetrakis(2-chloroethyl) bisphosphate |
| WAC | Washington Administrative Code |
| XRF | X-ray fluorescence |

## Data Flags

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ The analyte was analyzed for and was not present above the level of the associated value. The associated numerical value may not accurately or precisely represent the concentration necessary to detect the analyte in this sample.

U The analyte was not detected at or above the reported sample quantitation limit.

## Units of Measurement

| | |
|---|---|
| ppm | part per million |

# Appendix 1. Information on the components sent to the Laboratory.

***Bolded green components were sent to both Laboratories.***

*Blue highlighted results are children's products.*

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| SK023-F03 | Fabric | Toys/Games | Baby Activity Gym | orange fabric covering all of base | - | ~.5% |
| **SK023-F06** | Fabric | Toys/Games | Baby Activity Gym | animal fabric on top of base of gym | - | |
| **SK025-F01** | Fabric | Toys/Games | Baby Activity Gym | red fabric on bottom of mat | - | |
| SK025-F03 | Fabric | Toys/Games | Baby Activity Gym | patterned fabric on top of mat | - | |
| SK024-F03 | Plastic | Baby Care | Baby Carrier | black mesh fabric | - | |
| **TR103-F01** | Fabric | Baby Care | Baby Carrier | light grey fabric | V6, TCEP, TCPP, TDCPP | |
| TR103-F12 | Fabric | Baby Care | Baby Carrier | composite of light and dark grey fabric | TCEP, TCPP, TDCPP | |
| TR019-F02 | Stuffing | Baby Care | Baby neck support | stuffing | - | |
| TR020-F02 | Stuffing | Baby Care | Baby neck support | stuffing | - | |
| **WM095-F01** | Styrofoam | Household/Office Furniture/Furnishings | Bean Bag Chair | poly foam beans | HBCD | + |
| TR018-F01 | Foam | Household/Office Furniture/Furnishings | Belly Pillow | inner foam | - | |
| **TG027-F01** | Foam | Baby Care | Booster Seat | interior foam | TDCPP, TCPP, TCEP | |
| **TG033-F01** | Stuffing | Household/Office Furniture/Furnishings | Booster Seat Pad | padding | - | |
| **TR105-F06** | Fabric | Baby Care | Car Seat | polka dotted fabric in seat | - | ~.5% |
| **TR105-F09** | Fabric | Baby Care | Car Seat | composite of green and brown fabric from head support | - | + |
| TR105-F11 | Fabric | Baby Care | Car Seat | dark brown fabric in seat | - | + |
| WM097-F01 | Foam | Baby Care | Car Seat Handle Cushion | gray exterior foamy fabric | - | |
| DT042-F02 | Foam | Baby Care | Changing mat | foam | - | |
| **TG024-F02** | Foam | Baby Care | Changing mat | foam | TDCPP, TCPP, TCEP | |
| TG028-F02 | Foam | Baby Care | Changing Pad | interior foam | TDCPP, TCPP, TCEP | |
| TR015-F01 | Foam | Baby Care | Changing Pad | interior foam | TCPP, TDCPP, TCEP | |
| MR000-F03 | Foam | Household/Office Furniture/Furnishings | Mattress | top foam under batting | - | |
| MR000-F06 | Fabric | Household/Office Furniture/Furnishings | Mattress | felt fabric under bottom fabric | - | |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| **CT006-F01** | Fabric | Baby Care | Mattress | cover fabric shiny side down | - | |
| CT006-F03 | Stuffing | Baby Care | Mattress | internal batting | - | |
| CT006-F04 | Foam | Baby Care | Mattress | top foam layer | - | |
| CT006-F05 | Foam | Baby Care | Mattress | internal thick foam | - | |
| **TG023-F01** | Fabric | Clothing | Pajamas | grey pjs | - | |
| TG051-F01 | Fabric | Clothing | Pajamas | PJ Fabric | - | |
| WM065-F01 | Fabric | Clothing | Pajamas | PJ Pant Fabric | - | |
| CP000-F01 | Fabric | Clothing | Pajamas | Fleece footie pjs | - | |
| FM040-F01 | Fabric | Clothing | Bathrobe | Bathrobe Fabric | - | |
| WM063-F01 | Fabric | Clothing | Bathrobe | Bathrobe fabric | - | |
| **AM007-F01** | Foam | Household/Office Furniture/Furnishings | Chair | arm rest foam | - | |
| **AM008-F01** | Foam | Household/Office Furniture/Furnishings | Chair | Foam | TPP | + |
| **AM009-F01** | Foam | Household/Office Furniture/Furnishings | Chair | Foam | TPP | |
| OS000-F02 | Foam | Household/Office Furniture/Furnishings | Chair | blue/green seat cushion foam | - | |
| OS000-F04 | Foam | Household/Office Furniture/Furnishings | Chair | pink body foam | - | |
| **OS001-F01** | Foam | Household/Office Furniture/Furnishings | Chair | foam | V6, TCPP, TCEP, TDCPP | |
| OS002-F01 | Foam | Household/Office Furniture/Furnishings | Chair | upper portion inner foam | TDCPP. TCPP. TCEP | |
| **OS003-F01** | Foam | Household/Office Furniture/Furnishings | Chair | head cushion fluff | TDCPP. TCPP. TCEP | |
| OS003-F03 | Foam | Household/Office Furniture/Furnishings | Chair | head cushion fluff yellow foam chunks | TDCPP, TCPP, TCEP | |
| **PB000-F01** | Foam | Household/Office Furniture/Furnishings | Chair | foam | TPP | + |
| **TG031-F01** | Foam | Household/Office Furniture/Furnishings | Chair | interior foam | TPP | + |
| TR097-F01 | Foam | Household/Office Furniture/Furnishings | Chair | chair foam | - | |
| **TR098-F01** | Foam | Household/Office Furniture/Furnishings | Chair | chair foam | TDCPP, V6, TCPP, TCEP | |
| WM094-F01 | Foam | Household/Office Furniture/Furnishings | Chair | cushion foam | TCPP, TDCPP, TCEP | |
| **OS004-F01** | Foam | Household/Office Furniture/Furnishings | Chair Accessory | foam from cushion | TDCPP, TCPP, TCEP | |
| CT000-F01 | Stuffing | Household/Office Furniture/Furnishings | Pillow | stuffing | - | |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| **TG029-F02** | Stuffing | Household/Office Furniture/Furnishings | Pillow | interior stuffing | - | |
| **TG030-F01** | Stuffing | Household/Office Furniture/Furnishings | Pillow | inner stuffing | - | |
| **BY002-F01** | Plastic | Toys/Games | Tablet | Tablet- for kid- plug | | + |
| BY002-F08 | Plastic | Toys/Games | Tablet | Tablet- for kid- green plastic around battery | PBD-ethane | + |
| **BY002-F11** | Plastic | Toys/Games | Tablet | Tablet- for kid- motherboard | - | ~.5% |
| **TR017-F01** | Foam | Baby Care | crib wedge | interior foam | TDCPP, TCPP, TCEP | |
| TR021-F02 | Foam | Baby Care | Pee protector | interior foam | TDCPP, TCPP, TCEP | |
| TR022-F02 | Foam | Baby Care | Pee protector | Foam | - | |
| **CT001-F01** | Stuffing | Toys/Games | Play Pad | Stuffing | - | |
| **TR016-F01** | Foam | Baby Care | Portable Crib Pad | interior foam | TDCPP, TCPP, TCEP | |
| TG026-F03 | Stuffing | Toys/Games | Security Blanket | owl stuffing | - | |
| TG025-F02 | Stuffing | Toys/Games | Stuffed Animal | stuffing | - | |
| DT037-F02 | Stuffing | Toys/Games | Stuffed Toy | stuffing | - | |
| DT039-F01 | Stuffing | Toys/Games | Stuffed Animal | Interior stuffing | - | |
| **FM042-F01** | Plastic | Beauty/Personal Care/Hygiene | Hair Dryer | Side of dryer | - | |
| BL008-F01 | Plastic | Electrical Supplies | 6 Outlet surge protector | Body of strip | - | |
| **BL036-F04** | Plastic | Computing | 7 inch internet tablet | 7 inch internet tablet- motherboard | - | + |
| CT002-F01 | Foam | Household/Office Furniture/Furnishings | Bath Mat | Foam | - | |
| **FM038-F01** | Plastic | Electrical Supplies | Battery Charger | Charger body | - | ~.5% |
| **OM000-F02** | Plastic | Electrical Supplies | Battery Charger | Silver body | TBBPA, TPP | + |
| WM066-F01 | Plastic | Electrical Supplies | Battery Charger | Charger body | TPP | |
| CT010-F02 | Plastic | Audio Visual/Photography | blue ray disc/dvd player | plastic exterior | - | |
| CT010-F05 | Plastic | Audio Visual/Photography | blue ray disc/dvd player | white plastic | TPP | |
| **CT010-F08** | Plastic | Audio Visual/Photography | blue ray disc/dvd player | larger motherboard | - | + |
| **WS002-F01** | Plastic | Automotive | Car charger | Side | TBBPA | + |
| HD000-F01 | Foam | Building Products | Carpet padding | Carpet padding | TDCPP, TPP, TCPP, TCEP | |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| **HD001-F01** | Foam | Building Products | Carpet padding | Carpet padding with red backing | TDCPP, TPP, TCPP, TCEP | |
| **LW000-F01** | Foam | Building Products | Carpet padding | Carpet padding | TDCPP, TPP, TCPP, TCEP, V6 | |
| LW001-F01 | Foam | Building Products | Carpet padding | Carpet padding | TDCPP, TCPP, TPP, TCEP | |
| **LW002-F01** | Foam | Building Products | Carpet padding | Carpet padding | TDCPP, TCPP, TPP, V6, TCEP | |
| **TG056-F01** | Plastic | Home Appliances | Ceramic Heater | Space heater side plastic | - | + |
| **CT003-F01** | Foam | Household/Office Furniture/Furnishings | Chair Pad | Foam | TDCPP, TCPP, TCEP | |
| **TG050-F01** | Plastic | Communications | Charger | Plug in | - | + |
| **FM043-F01** | Plastic | Home Appliances | Clothing Iron | Silver plastic closest to heating element | TBBPA | + |
| FM043-F02 | Plastic | Home Appliances | Clothing Iron | Cord | - | |
| **WM069-F01** | Plastic | Home Appliances | Coffee Pot | Bottom plastic closest to heating element | - | + |
| FM039-F01 | Plastic | Electrical Supplies | compact power station | Charger body | - | |
| BB000-F02 | Plastic | Home Appliances | Dehydrator | grey plastic around top | - | |
| BB000-F03 | Plastic | Home Appliances | Dehydrator | grey plastic around top | - | |
| **BB000-F04** | Plastic | Home Appliances | Dehydrator | grey plastic above coil | - | + |
| GR008-F01 | Plastic | Electrical Supplies | Electrical Supply | | - | |
| **FM041-F01** | Plastic | Home Appliances | Fan Forced Heater | Space heater side plastic | - | + |
| **WM070-F01** | Plastic | Home Appliances | Fan-Forced Heater | Space heater side plastic | - | |
| GR014-F01 | Oil/Solvent | Home/Business Safety/Security/Surveillance | Fire Retardant spray | liquid spray | - | |
| **GR015-F01** | Plastic | Lawn/Garden Supplies | Flame resistant drainage tarp | Flame resistant drainage tarp plastic | - | + |
| GR010-F01 | Plastic | clothing | Flame resistant lab coat | blue lab coat fabric | - | |
| GR013-F02 | Plastic | Electrical Supplies | flame resistant sleeve | blue elastic fabric | - | |
| GR012-F01 | Plastic | Home/Business Safety/Security/Surveillance | Flame retardant pad | blue pad fabric | - | |
| GR012-F02 | Stuffing | Home/Business Safety/Security/Surveillance | Flame retardant pad | Stuffing | - | |
| TG053-F01 | Plastic | Communications | Flip Phone | Phone-battery side | - | |
| HD002-F01 | Foam | Camping | foam camping pad | foam camping pad | - | |
| CT007-F01 | Fabric | Household/Office Furniture/Furnishings | Foam Pillow | external cloth cover | - | |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| CT007-F02 | Fabric | Household/Office Furniture/Furnishings | Foam Pillow | internal cloth protector | - | |
| CT007-F03 | Foam | Household/Office Furniture/Furnishings | Foam Pillow | internal gel blue beads | - | |
| CT007-F04 | Foam | Household/Office Furniture/Furnishings | Foam Pillow | internal white foam | - | |
| TG052-F01 | Plastic | Beauty/Personal Care/Hygiene | Hair Dryer | Side of dryer | - | |
| WM067-F01 | Plastic | Beauty/Personal Care/Hygiene | Hair Dryer | Purple outer plastic | - | |
| WM067-F03 | Plastic | Beauty/Personal Care/Hygiene | Hair Dryer | cord | - | |
| **BL005-F01** | Plastic | Beauty/Personal Care/Hygiene | Hair Flat Iron | Outside of flat iron | TBBPA | + |
| BL005-F03 | Plastic | Beauty/Personal Care/Hygiene | Hair Flat Iron | Inner plastic - near element | - | |
| BL003-F01 | Plastic | Home Appliances | Hand Mixer | Side of mixer | - | |
| WM068-F01 | Plastic | Household/Office Furniture/Furnishings | Heated mattress foot warming pad | Heat pad | - | |
| WM068-F02 | Plastic | Household/Office Furniture/Furnishings | Heated mattress foot warming pad | Top of controller | - | + |
| WM068-F03 | Plastic | Household/Office Furniture/Furnishings | Heated mattress foot warming pad | Bottom of controller | TBBPA | + |
| **WM068-F04** | Plastic | Household/Office Furniture/Furnishings | Heated mattress foot warming pad | Connector | - | + |
| BL009-F01 | Fabric | Household/Office Furniture/Furnishings | Heated Throw | Blanket Fabric | - | |
| **BL009-F03** | Plastic | Household/Office Furniture/Furnishings | Heated Throw | Large cord | - | |
| HD004-F01 | Fiberglas | Building Products | Insulation | Fiberglas insulation | - | |
| BB001-F01 | Fabric | Home Appliances | Ironing Board Cover | beige cover | - | |
| GR006-F01 | Fabric | Home Appliances | Ironing Board Cover | exterior fabric | - | |
| **OM005-F08** | Plastic | Computing | LCD Monitor | largest motherboard - green one side tan the other | TPP | + |
| **OM005-F09** | Plastic | Computing | LCD Monitor | medium motherboard - green both sides | - | + |
| OM005-F10 | Plastic | Computing | LCD Monitor | plastic back | - | |
| **CT009-F03** | Plastic | Audio Visual/Photography | LED TV | plastic covering power input | - | + |
| CT009-F08 | Plastic | Audio Visual/Photography | LED TV | power supply | - | |
| CT009-F09 | Plastic | Audio Visual/Photography | LED TV | cable connector | - | |
| **CT009-F12** | Plastic | Audio Visual/Photography | LED TV | Mother board from TV | - | + |
| BL037-F02 | Foam | Household/Office Furniture/Furnishings | Mattress | top batting | - | |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| CT008-F01 | Foam | Household/Office Furniture | Mattress Pad | Foam | - | |
| DT044-F02 | Fabric | Clothing | Oven Mitt | | - | |
| GR005-F01 | Fabric | Clothing | Oven Mitt | oven mitt | - | |
| **BL004-F01** | Plastic | Home Appliances | Personal Heater Fan | Space heater side plastic | - | + |
| OR000-F01 | Plastic | Storage/Haulage Containers | Plastic Pallet | structural foam pallet black | - | |
| BC000-F01 | Plastic | Storage/Haulage Containers | Plastic Pallet | Plastic | - | |
| GR000-F01 | Plastic | Storage/Haulage Containers | Plastic Pallet | Black | - | |
| GR001-F01 | Plastic | Storage/Haulage Containers | Plastic Pallet | recycled plastic pallet | - | |
| UL000-F01 | Plastic | Storage/Haulage Containers | Plastic Pallet | Plastic Pallet | - | |
| WS001-F01 | Plastic | Camping | Pot and Pan Support | Camp stove converter-Orange Plastic stand | - | |
| HD005-F01 | Plastic | Home Appliances | Power Cord | cord casing | - | |
| **BY000-F01** | Plastic | Computing | Projector | Projector-Top plastic casing | - | |
| **WS006-F01** | Plastic | Camping | Propane Heater | Side Casing | - | + |
| GR002-F01 | Fabric | Clothing | Protective Clothing | yellow fabric | - | |
| **GR003-F01** | Plastic | Clothing | Protective Glove | glove rubber palm fabric | HBCD | |
| WW000-F01 | Plastic | Clothing | Protective Gloves | black rubber surface | - | |
| WW001-F01 | Plastic | Clothing | Protective Gloves | Vinyl glove | - | |
| WS004-F01 | Plastic | Automotive | Quick Jumper Cables | Yellow Casing | - | |
| LW004-F01 | Plastic | Home Appliances | range receptacle | big black plastic connector | - | + |
| DS000-F01 | Fabric | Clothing | Reflective Clothing | Orange Fabric | - | |
| **DS000-F02** | Plastic | Clothing | Reflective Clothing | | - | |
| MW000-F01 | Fabric | Clothing | Reflective Vest | Orange Fabric | - | |
| **MW000-F02** | Fabric | Clothing | Reflective Vest | yellow fabric | - | |
| SG000-F01 | Plastic | Clothing | Reflective Vest | Reflective tape | - | |
| **SG000-F02** | Fabric | Clothing | Reflective Vest | Fabric | - | |
| **PO001-F01** | Foam | Household/Office Furniture/Furnishings | Seat Cushion | red fabric | TDCPP, TCPP, TCEP | |
| OM003-F01 | Plastic | Stationery/Office Machinery/Occasion Supplies | Shredder | Large grey plastic holder piece | TPP | + |

| Component ID | Material | Segment | Product Description | Component | Flame retardant detected in order of relative abundance | XRF Br > 1% |
|---|---|---|---|---|---|---|
| **OM003-F02** | Plastic | Stationery/Office Machinery/Occasion Supplies | Shredder | top plastic | TBBPA, TPP | + |
| **CA002-F01** | Fabric | Camping | Tent | Tent- black tent fabric | TDCPP, V6, TCEP | |
| CA002-F02 | Fabric | Camping | Tent | Tent- silver tent fabric | TDCPP, TCEP, TCPP | |
| **CA001-F01** | Fabric | Camping | Tent floor liner | Tent floor liner- green fabric | TDCPP, TCEP | |
| FM044-F01 | Plastic | Home Appliances | Toaster | Plastic ends of toaster | - | |
| **TG057-F01** | Plastic | Home Appliances | Toaster | Side of plastic toaster | - | |
| WM071-F01 | Plastic | Home Appliances | Toaster | Side of plastic toaster | - | |
| CA000-F01 | Fabric | Camping | Tube Tent | Tube Tent- Emergency Shelter- orange plastic | - | |
| RS001-F01 | Plastic | Computing | Wireless Router | Wireless Router-Case | - | |

## Appendix 2
## Components containing target analytes above 1000 ppm from ALS or MEL

| Component ID | Analyte | ALS result (ppm) | MEL result (ppm) | % RPD | Material |
|---|---|---|---|---|---|
| CA001-F01 | TDCPP | 6190 | 4300 | 36.0 | Fabric |
| CA002-F01 | TDCPP | 34900 | 19000 J | 59.0 | Fabric |
| CT003-F01 | TDCPP | 36200 | 21000 J | 53.1 | Foam |
| HD001-F01 | TDCPP | 9880 J | 4100 J | 82.7 | Foam |
| LW000-F01 | TDCPP | 8430 | 84000 J | 163.5 | Foam |
| LW002-F01 | TDCPP | 2550 | 1800 J | 34.5 | Foam |
| OS003-F03 | TDCPP | 56600 | 29000 J | 64.5 | Foam |
| OS004-F01 | TDCPP | 8000 | 7000 J | 13.3 | Foam |
| PO001-F01 | TDCPP | 37900 | 33000 | 13.8 | Foam |
| TG024-F02 | TDCPP | 49500 | 15000 J | 107.0 | Foam |
| TG027-F01 | TDCPP | 124000 | 44000 J | 95.2 | Foam |
| TG028-F02 | TDCPP | 65400 | 25000 J | 89.4 | Foam |
| TR016-F01 | TDCPP | 38200 J | 16000 J | 81.9 | Foam |
| TR017-F01 | TDCPP | 56800 | 25000 J | 77.8 | Foam |
| TR098-F01 | TDCPP | 87100 | 26000 | 108.0 | Foam |
| OS003-F01 | TDCPP | 926 J | 1600 | 53.4 | Foam |
| OS001-F01 | TCEP | 3530 | 3400 J | 3.8 | Foam |
| OS003-F03 | TCEP | 2390 | 2100 J | 12.9 | Foam |
| TR098-F01 | TCEP | 3930 | 3000 J | 26.8 | Foam |
| TR103-F01 | TCEP | 8490 | 2700 | 103.5 | Foam |
| CT003-F01 | TCPP | 3720 | 3000 | 21.4 | Foam |
| LW000-F01 | TCPP | 1040 | 690 | 40.5 | Foam |
| OS001-F01 | TCPP | 20900 | 12000 | 54.1 | Foam |
| OS003-F03 | TCPP | 16600 | 12000 J | 32.2 | Foam |
| PO001-F01 | TCPP | 6830 | 7000 J | 2.5 | Foam |
| TG024-F02 | TCPP | 3200 | 2800 J | 13.3 | Foam |
| TG027-F01 | TCPP | 43200 | 15000 | 96.9 | Foam |
| TG028-F02 | TCPP | 3990 | 4900 J | 20.5 | Foam |
| TR016-F01 | TCPP | 29300 | 9700 | 100.5 | Foam |
| TR017-F01 | TCPP | 8230 | 7700 | 6.7 | Foam |
| TR098-F01 | TCPP | 19300 | 16000 | 18.7 | Foam |
| TR103-F01 | TCPP | 1690 | 640 J | 90.1 | Foam |
| AM008-F01 | TPP | 13500 | 10000 J | 29.8 | Foam |
| AM009-F01 | TPP | 35300 | 29000 J | 19.6 | Foam |
| HD001-F01 | TPP | 2710 J | 2700 | 0.4 | Foam |
| LW002-F01 | TPP | 1150 | 560 | 69.0 | Foam |
| OM005-F08 | TPP | 37800 | 21000 | 57.1 | Plastic |
| PB000-F01 | TPP | 7770 | 6300 | 20.9 | Foam |
| TG031-F01 | TPP | 13200 | 13000 J | 1.5 | Foam |