  

An assessment of persistent organic pollutants (POPs) in waste domestic seating

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Glossary

BFR	Brominated flame retardants
Br-PFR	Brominated-phosphorous flame retardant
c-decaBDE	Commercial decaBDE formulation
c-octaBDE	Commercial octaBDE formulation
c-pentaBDE	Commercial pentaBDE formulation
Cl-PFR	Chlorinated-phosphorous flame retardant
DecaBDE	Decabromodiphenyl ether
EA	Environment Agency
EfW	Energy from waste
FR	Flame retardant
GC HRMS	Gas chromatography high resolution mass spectrometry
HBCDD	Hexabromocyclododecane
HeptaBDE	Hexabromodiphenyl ether
HexaBDE	Hexabromodiphenyl ether
HWRC	Household waste recycling centre
LC-MS	Liquid chromatography mass spectrometry
LOD	Limit of detection
MCCP	Medium chain chlorinated paraffin
MCL	Maximum concentration limit
NonaBDE	Nonabromodiphenyl ether
OctaBDE	Octabromodiphenyl ether
PBDE	Polybrominated diphenyl ether
PentaBDE	Pentabromodiphenyl ether
PFR	Phosphorous flame retardants
POP	Persistent Organic Pollutant
PVC	Polyvinyl chloride
SCCP	Short chain chlorinated paraffin
TBBPA	Tetrabromobisphenol A
TetraBDE	Tetrabromodiphenyl ether
TriBDE	Tribromodiphenyl ether
WRc	Water Research Centre
WTS	Waste transfer station
XRF	X-ray fluorescence

Summary

WRc were commissioned by the Environment Agency to undertake a sampling and characterisation programme of waste domestic seating. The project aimed to assess whether brominated flame retardants (BFRs) classified as persistent organic pollutants (POPs) are present in waste domestic seating. The project had a particular focus on polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCDD) which are POPs classified BFRs and which are known to have be added to domestic seating in the past.

In November 2020, WRc took 282 samples of waste domestic seating from six sites in England. Five of those sites were 'waste' sites which included an energy from waste facility, two waste transfer stations, two household waste recycling centres and one re-use charity.

Samples of textile components from domestic seating items were taken. These included samples of covers, foams, linings and other textiles e.g. wadding and elastic straps. The components were taken to WRc's laboratories to undergo a three-tiered chemical assessment. In the first tier, all the sampled components (282 items) underwent chemical screening using X-ray fluorescence (XRF) analysis to test for the presence of bromine. This exercise highlighted samples which may contain BFRs. A selected number underwent a second and/or third tier of assessment, which involved semi-quantitative and qualitative analysis of PBDEs and other flame retardants using more selective analytical method.

The Tier 1 results provide the typical bromine concentrations found in textile components in UK waste domestic seating. The results across all sites showed similar bromine concentrations in the textile components demonstrating that the sampling programme has provided a good cross-section of UK domestic seating. Bromine was most frequently detected in textile covers with over half (54%) of all covers containing bromine concentrations at >1% wt. The results showed that 97% of leather covers had a bromine concentration <0.1% wt. indicating that BFRs are not commonly added to leather covers (only a single cover identified as leather contained bromine). However, bromine was detected in 19% of synthetic leather or 'leatherette' samples at concentrations of >1% wt. Further characterisation of synthetic leather revealed that these covers are made from various polymers including polyvinyl chloride, polyester, polypropylene and polyurethane.

Bromine was detected in foam samples, but only 6% contained bromine at concentrations of >1% wt. Bromine was sometimes detected in foams even when it was not detected in the covers indicating that several types of flame retardants could be present in the differing components within a single domestic seating item.

The determination of the weights of the various textile components in the domestic seating items allowed for their relative proportions to be determined i.e. covers account for between

approximately 15 to 25% of the weight of an entire sofa. This means that if bromine was present as decaBDE at functional levels (>1% wt.) the sofa should be described as a POPs waste.

Testing in Tiers 2 and 3 determined which FRs were present in the domestic seating components. The results showed that POPs-classified BFRs are present in a proportion of waste domestic seating at concentrations that would result in a POPs classification. Of the textile covers which were tested in Tier 3, 81% were found to have concentrations of decaBDE or HBCDD at levels which would result in a POPs classification for the entire item. No differences in the concentrations of these chemicals were observed between textile sofas, armchairs or chairs. Coupled with the results of the XRF screening, the data suggests that POPs-classified BFRs are prevalent in waste textile domestic seating. The results also showed 25% of leatherette covers contained POPs-classified BFRs at concentrations which would result in a POPs classification. One foam sample and one lining sample were found to contain decaBDE at concentrations above 1% wt., and another lining sample contained HBCDD at a concentration around 0.6% wt.

Analyses showed that for the lining and foams there were a significant number of samples with ‘missing bromine’ i.e. bromine detected by XRF but not accounted for by HBCDD or PBDE analysis. This may be due difficulties in extractions of the brominated compounds associated with the matrix in which they are found, which impacts the quantitative and qualitative analysis. It also indicates that other brominated compounds may be present. Some samples tested were found to contain DBDPE (decabromodiphenyl ethane) but none were found to contain the common flame retardant TBBPA (tetrabromobisphenol A). It is also possible some samples contain polymeric flame retardants which consist of a co-polymer of a brominated polymer and another such as styrene. If present, they are unlikely to be extracted during testing and so would not be accounted for. These are more likely to be present in foam samples due to their known use in expanded polystyrenes.

Chlorinated phosphorous based flame retardants have also been detected in a number of samples during both Tier 2 and Tier 3 analysis. These compounds are not currently POPs classified but may require monitoring in the future.

A significant number of samples were found to contain decaBDE alongside compounds typical of a commercial decaBDE flame retardant formulation, namely nonaBDE and antimony (antimony trioxide).

Despite difficulties experienced during analytical testing, these challenges have mainly been overcome by the expertise of the test laboratories. Interlaboratory verification of results, with few inconsistencies, showed beyond reasonable doubt that the concentration of POPs in domestic seating exceeds thresholds. The data does indicate that testing these types of matrices is extremely difficult and application of current standard methods may not be sufficient. Technical expertise in this instance has been used to overcome a variety of complex analytical issues to generate a robust dataset to support regulatory decision making.

The data presented in this report indicates that POPs-classified components can be found predominately in the covers of textile and leatherette domestic seating, but not those made from natural leather. Taking into account the proportion of POPs containing components in the total units the data suggests that some items of waste domestic seating should be classified as POPs waste and therefore undergo suitable end of life waste management.

The data produced from the sampling and testing of domestic seating has been used to estimate the amount of POPs-classified brominated flame retardants in UK domestic seating waste. Based on the results from this study, there is between 364 and 476 tonnes of POPs-classified brominated flame retardants per 100,000 tonnes of waste domestic seating. The majority of the POPs are likely to be decaBDE based on the results of the Tier 3 testing. Textile covers from sofas account for 88% of the POPs in the waste stream and when combined with the textile covers from armchairs account for 94%. This is due to the high brominated concentrations found in a large proportion of the textile covers tested and the overall weight of these items in the total weight of the unit.

1. Introduction

1.1 Brominated Flame Retardants and Persistent Organic Pollutants

To comply with fire safety regulations, domestic seating must contain flame retardants or incorporate design features (such as layers of different fabrics) to reduce their flammability and limit serious fires. However, some chemicals, which were previously legitimately used as flame retardants, have now been designated as being persistent in the environment as well as carcinogenic and / or toxic to humans, animals and aquatic organisms. Brominated flame retardants (BFRs) such as some PBDEs (polybrominated diphenyl ethers) are a class of persistent organic pollutants (POPs).

The POPs Regulations[1] implements the Stockholm convention and sets a maximum concentration limit of 1,000 mg kg^{-1} for the sum of POPs-classified PBDEs which are as follows:

- tetrabromodiphenyl ether (tetraBDE);
- pentabromodiphenyl ether (pentaBDE);
- hexabromodiphenyl ether (hexaBDE);
- heptabromodiphenyl ether (heptaBDE); and
- decabromodiphenyl ether (decaBDE).

Additionally, a maximum concentration limit (MCL) of 1000 mg kg^{-1} in waste is set for hexabromocyclododecane (HBCDD) in the POPs Regulation. When wastes contain POPs above the MCL, they must be treated in such a way that the POPs are destroyed or irreversibly transformed.

It is known that decaBDE and HBCDD have been used in domestic seating sold in the UK. DecaBDE was listed as a substance of very high concern (SCHC) in 2012 by REACH and in February 2017 the REACH registration of decaBDE was published. The provisions set out in this registration came into force in the EU which ban the use of decaBDE in quantities greater than 0.1% wt.. Phasing out of decaBDE (and other BFRs) occurred throughout various industries before this time. However, it is likely that items of domestic seating which are now

[1] The Persistent Organic Pollutants (Amendment) (EU Exit) Regulations 2020 No. 1358

entering the UK's waste streams were manufactured during the time when these chemicals were in use.

1.2 Waste Domestic Seating

The purpose of this study was to determine whether POPs-classified BFRs were present in UK waste domestic seating such as sofas and armchairs. It also aimed to identify which components within seating units are most likely to contain these chemicals and if so whether the concentration would be high enough so that the entire item (by weight) should be classified as a POPs waste. An assessment of the chemical composition of these items informs an accurate description that would help to ensure that when they reach their end of life, they undergo appropriate waste management. This would reduce the likelihood that these chemicals would enter the wider environment. The current practice for waste domestic seating in the UK is to send the items to energy from waste (EfW) facilities or landfill.

Waste domestic seating are produced by domestic households and are usually large bulky items such as sofas and armchairs which contain various components such as coverings, foams, inner linings, and wooden and / or steel frameworks. These items can be discarded from households in several ways. They can be taken to household waste recycling centres (HWRCs), collected as bulky waste collections (BWCs), via a commercial take-back scheme, or donated to charity for reuse.

According to a WRAP report, most domestic seating are discarded as waste and only a small proportion is sent for reuse[2]. In the same report, the HWRC and BWC streams were shown to account for over 95% of sofas discarded from households whereas voluntary collections account for only a small proportion. When domestic seating like sofas are collected at HWRCs or from BWCs, they are usually inspected to determine whether they can be reused and donated to local charities. Approximately 20% of domestic seating are sent for reuse and the remaining proportion are sent for recycling, energy from waste or landfill.

Typically, the HWRC and BWC waste will be sent to a waste transfer station (WTS) where the items will be bulked ahead of being sent for further processing, for example, mechanical treatment and / or thermal treatment. In addition to a WTS being the intermediate destination for HWRC and BWC domestic seating, it is commonplace for units collected by trade take-back schemes to be delivered to the same location. In some areas, instead of the domestic seating going to a WTS, they are sent directly to an energy from waste facility where they are incinerated.

To approach this study, WRc devised a sampling plan to recover a representative cross-section of samples from the UK domestic seating waste stream which included textiles and polymer

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[2] Benefits of Reuse Case Study: Domestic Furniture WRAP November 2011

materials for chemical testing. Fundamentally the approach was developed to produce a dataset representative of the national domestic seating waste stream based on the information discussed above.

Following site sampling a three-tiered testing strategy was implemented. This involved initial screening for bromine and other metals using a handheld X-ray fluorescence (XRF) analyser (Tier 1). Tier 1 screening highlighted a cross-section of samples to undergo additional laboratory testing for broad screening of commonly used FRs in fabric and polymer foams to produce semi-quantitative compound analysis (Tier 2). Finally chemical extraction and quantitative laboratory analysis was used to test for PBDEs and other flame retardants identified in the screening process (Tier 3).

1.3 Flame Retardants in Domestic Seating

Flame retardants can be added to textiles in a number of ways. **Reactive** flame-retardants are added during the polymerisation process and become an integral part of the polymer and form a co-polymer with the fabric. The result is a modified polymer with flame retardant properties and different molecular structure compared to the original polymer molecule. **Additive** flame-retardants, which include PBDEs, are incorporated into the polymer prior to, during, or more frequently after polymerisation as a coating. Additive flame-retardants are monomer molecules that are not chemically bonded to the polymer and can be considered chemically discrete surface areas of a manufactured article. They are commonly added with metal oxide synergists to improve their performance. They may therefore, in contrast to reactive flame retardants, be released from the polymer during normal use and thereby also discharged to the environment. In contrast to many additives, chemical flame-retardants can appreciably impair the properties of polymers. So, there is a trade-off between the decrease in performance of the polymer caused by the flame retardant and fire retardancy requirements. In the case of fabrics that are designated as “flame retardant,” which have been topically treated with chemicals, the flame retardancy of the fabric is likely to dissipate over time, particularly with repeated cleaning and at end of life they may no longer contain functional levels of FRs.

1.3.1 Brominated flame retardants other than PBDEs and HBCDD

The phase out of PBDEs has led to an increase in use of other halogenated flame retardants (HFRs) which are primarily based on chlorine and bromine such as TBBPA (Tetrabromobisphenol A) and phosphorus-based flame retardants.

Flame retardants can be added as formulations which can contain a mixture of chemicals. The PBDEs normally added as commercial formulations include:

- commercial-pentaBDE (c-pentaBDE), composed of tetra, penta and hexaBDE (an old formulation used in polyurethane foams);
- commercial-octaBDE (c-octaBDE), mainly composed of hepta, octa and decaBDE; and

- commercial-decaBDE (c-decaBDE), mainly composed of decaBDE.

The PBDE formula most likely to be present in waste domestic seating is c-decaBDE as the c-pentaBDE and c-octaBDE formulations were phased out prior to c-decaBDE's use. However, as the age of waste domestic seating will vary, possibly over a 30-year period, these older formulations could still be present in some items.

Tetrabromobisphenol A (TBBPA) is an example of a commonly used BFR which is not currently classified as a POP. It is primarily used as a 'reactive' flame retardant and forms an integral part of the polymer to which it is added, but can be used as an additive flame retardant in the manufacture of some polymers. Although a main use of this chemical is as a flame retardant for epoxy resin polymers, for example in printed circuit boards it can have uses in textiles (but only polymer-based textiles). Other brominated flame retardants which have been identified as alternatives for commercial PBDE formulations are ethylene bis(tetrabromophthalimide) (EBTBP) and decabromodiphenyl ethane (DBDPE).

Ethylene bis(tetrabromophthalimide) is an additive fire retardant that is added to a polymer mixture to produce a blend which is primarily used in electrical and electronics components, wire and cable insulation, switches etc. It is commonly used in high impact polystyrene (HIPS), polyethylene, polypropylene, thermoplastic polyesters, polyamide, ethylene propylene-diene terpolymers (EPDM rubbers) and other synthetic rubbers, polycarbonate, ethylene copolymers, ionomer resins and epoxies but it is also used in some textile treatments.

Decabromodiphenyl ethane (DBDPE) is a BFR which is structurally similar to decaBDE and has therefore been used as a dec-BDE replacement flame retardant in textiles. The application of DBDPE to textiles is similar to decaBDE and it can be added in formulations with metal oxide synergists such as antimony trioxide in DBDPE-ATO formulations. Due to its similarity with decaBDE, there is some concern about the effects of DBDPE and the chemical is currently being evaluated under REACH for its persistence, bioaccumulation and toxicity. However, there are currently no restrictions on its use in textiles or other plastics.

XRF screening can be used to provide supporting evidence for the presence of many chlorinated or brominated flame retardants especially where they are added with metal oxide synergists, For example the potential presence of decaBDE is commonly linked with antimony trioxide as the metal oxide synergist. The decaBDE/ATO formulation was widely used in textiles and therefore the bromine concentration coupled with the antimony concentration provides a good indication that the bromine may be present as decaBDE.

1.3.2 Phosphorus flame retardants

Another group of flame retardants, which have been increasingly used since many brominated products were designated as POPs are phosphorous flame retardants (PFRs). PFRs can be divided in three main groups, inorganic, organic and halogen containing PFRs. Most of the

PFRs have a mechanism of action in the solid phase of burning materials (char formation), but some may also be active in the gas phase.

Some phosphorous based flame retardants (PFRs) contain bromine, although they are reportedly less common than chlorinated-PFRs or other non-halogenated PFRs.

Tris(2,3-dibromopropyl) phosphate was briefly used in the 1970s, but was subsequently withdrawn from use due to fears surrounding it possible carcinogenic effects. Tris(2,4-dibromophenyl) phosphate is a similar chemical but is reportedly not commercially available and so unlikely to be present in domestic seating textiles.

Formulations of ammonium phosphates and ammonium bromide are sold for use on cellulosic–synthetic fibre blends and tris(tribromoneopentyl) phosphate can be added to polyolefins which can be used for some foams. Inorganic phosphinates (hypophosphites): aluminium phosphinate Phoslite IP-A and calcium phosphinate (Phoslite IP-C) are claimed to be useful when added as mixed formulations in thermoplastics such as polypropylene with halogenated (particularly brominated) flame retardants.

1.3.3 Brominated polymeric flame retardants

Brominated polymeric flame retardants were developed as alternatives for HBCDDs to act as flame retardants in foams. It is a co-polymer of styrene and a brominated butadiene. The bromine, which provides the flame retardant properties, is bound to the polymer structure. The retardant contains similar aliphatic bromine as in HBCDD but with a higher molecular weight structure. These are a further example of 'reactive' flame retardants and have been used in expanded polystyrene and extruded polystyrene foams. The flame retardancy properties of these 'poly-FRs' are reported to be superior to the HBCDDs which they were intended to replace. The environmental risks of poly-FRs are thought to be lower than other brominated flame retardants, but research in this area is still on-going.

1.3.4 Brominated azo dyes

Following the classification of some BFRs as POPs, several studies have investigated the presence of brominated compounds in indoor house dusts (Dhungana *et al.*, 2019) (Peng *et al.*, 2016). The studies have identified that in addition to being present as flame retardants, bromine is also present in house-dust produced from fabric and carpet dyes in the form of brominated azo dyes.

Currently more than 3000 azo dyes have been developed for a broad spectrum of colours and represent more than 65% of the global dye market (Benkhaya, M'rabet and El Harfi, 2020). The azo dyes are synthetic dyes formed by azo groups which consists of two nitrogen atoms linked with each other. These dyes are not directly applied on the fabrics but, they are added within the fibres themselves producing bright and resistant tones of colour. Although published literature is sparse it is reported (Peng *et al.*, 2016) that a large group of brominated compounds in house dusts are attributable to the azo dyes family. Three brominated azo-dye compounds identified in house dust include Disperse Blue 373, Disperse Violet 93, Disperse Orange 61 and 2-bromo-4,6-dinitroaniline (Dhungana *et al.*, 2019).

There is very little information available on about how widely used these compounds are or their typical addition rates to textiles. If they are present, then they could be detected by their bromine content during XRF screening. These alternative BFRs and bromine compounds may be present in domestic seating although possibly only those manufactured recently. XRF screening is only used as guide and is supported by further laboratory analysis to identify whether the bromine is present as PBDEs or another flame retardant.

Unfortunately, XRF used to detect bromine is not able to determine the presence of lighter elements such as phosphorous and aluminium which appear to be key indicators of some PFRs. Therefore, additional testing was undertaken on some of the laboratory samples to assess whether they did contain PFRs to provide some indication on whether they were likely to impact the PBDE reporting due to complex interactions between the chemicals during extraction.

2. Sampling

2.1 Site Based Sampling

The aim of the sampling programme was to produce a robust dataset which was a representative cross section of the waste domestic seating produced in the UK. WRc sent site teams to take samples of domestic seating from five waste sites and a single re-use charity. The site visits were conducted after liaison with the operators to ensure that the samples collected would be representative of the typical waste domestic seating received at each site. The site visits were undertaken in November 2020 and, despite some disruption to the volumes of domestic seating seen at the sites due to the Covid-19 pandemic, the samples obtained are considered to be a good cross section of the type and quality of waste domestic seating in the UK at the time of the study.

The five waste sites included two Household waste recycling centres (HWRCs), two waste transfer stations (WTSs) and one energy from waste (EfW) facility in addition to the single re-use charity, their locations are shown in Table 2.1. All sites received their waste from a wide catchment area across their respective counties covering a range of demographics providing confidence that the samples obtain were representative of the UK waste stream as a whole.

Table 2.1 Sampling dates and locations

Site	Sampling date (2020)	Location	Type of facility
Site 1	9th November	Somerset	WTS
Site 2	9th November	Hampshire	WTS
Site 3	16th November	Worcestershire	EfW
Site 4	17th November	Leicestershire	HWRC
Re-use	24th November	Bristol	Re-use charity
Site 5	25th November	Buckinghamshire	HWRC

Where space was available, for example at the EfW facility, the operator pre-stockpiled domestic seating items for sampling. At most site items were randomly sampled as and when they were delivered in multiple consignments during the site visit. At the re-use charity, all domestic seating items were sampled from the warehouse and the adjacent shop.

Each domestic seating item or 'unit' was photographed and where possible the following information was obtained:

- item category and sub-category (three seater sofa, two seater sofa, etc.);

- weight;
- colour;
- age;
- flammability label (yes/no);
- country of manufacture;
- material description (textile, leather, plastic, etc.);
- brand; and
- approximate dimensions.

Not all this information was always available for every item and only 20% of the items sampled were found to have a flammability or fire safety label. The information which has been gathered from the sampling is provided in Appendix B. There does not seem to be a correlation between having a fire label and bromine being present. There are plenty of units with labels and no bromine. There are also examples in this table (but obviously in the rest of the dataset) where bromine is present without a fire label, but this might be because it has been removed.

Many units, particularly those discarded as waste were damaged or had pieces missing. It is likely that many owners had removed flammability labels from the items as well as any branding. Nevertheless, the site teams were able to obtain good information about the materials used for coverings and the category/sub-category which the units belonged to.

During the sampling of a 'unit', necessary but not complete dismantling was undertaken to enable access to textile or foam components. Each unit was photographed and a sample was taken of each textile or foam component. Each item was labelled and placed into a sampling bag ahead of return to WRc for screening using XRF.

The types of textile or foam components which were recovered from domestic seating included:

- fabric covers;
- foam cushions;
- polymer back casings;
- textile linings (i.e. on the underside of chairs and stools); and
- internal textiles.

Each textile or foam sample was dried (if necessary), measured for its dimensions and weighed. This was to determine the weight per unit area or volume so that the relative weight of the component to the entire unit could be determined. This allowed the concentrations of key chemicals such as 'total' bromine or decaBDE in a specific component to be converted to the concentration in the entire unit. This was important for waste POPs assessment and description purposes and the calculation method is outlined in Section 3.5.

During the site visit at the re-use charity, the domestic seating were not dismantled, or any samples removed from them. Instead *in-situ* chemical screening was undertaken using a handheld XRF analyser. All easily accessible textile or foam components were scanned using the XRF analyser to test for the presence of bromine. This is the same approach used in the chemical screening of the waste domestic seating samples which was performed at WRc's laboratories rather than 'on-site'. Therefore, no samples of re-use domestic seating were sent for further laboratory testing to avoid the need to purchase and then destruct items which were destined for reuse. However, the chemical screening results showed no observable differences in the chemical composition of domestic seating as waste or for re-use and therefore laboratory testing results are considered to be characteristic of domestic seating across all waste streams. This will be discussed in more detail later in the report.

2.2 Sample Breakdown

Across the sampling campaign, a total of 282 items were sampled, from which 985 components were taken back to WRc for XRF chemical screening. The components sampled from the waste sites were taken for XRF scanning, whereas for any items at the reuse charity scanning took place in-situ.

The breakdown of the items sampled from each site are given in Table 2.2 and Figure 2.1 below.

Most of the items sampled on each site visit were sofas. These included standard or reclining two-seaters or three-seaters, sofa beds and five-seater corner sofas. The next significant category of item were armchairs, including club (or rolled arm), wingback, tub or bucket and recliners. Chairs were also found on all sites, but much less often than sofas or armchairs. These were typically found in the form of dining or office chairs. Any bespoke or more unique items were categorised as "Other", which includes domestic seating such as footstools, beanbag chairs, and bed-bases or headboards. The number of items sampled from Site 1 and Site 2 were significantly less than from the other sites, as full weighing and measuring was undertaken at these sites, which may explain why the proportions of the items sampled by item category are skewed more towards individual categories (i.e. "sofas" for Site 1 and "chairs" for Site 2). Overall, the proportion of each category of item found in each of the site visits was generally consistent. This gives confidence that the items sampled during this project are representative of the current overall UK waste stream for domestic seating. Typical examples of items from each of the categories shown in Table 2.3

During the waste site visits samples of textile components were taken from the items. From all types of items similar components were recovered. Each item typically contained a cover which was either a textile, leather or synthetic leather; foam used for the seating and inner layers of textile; and 'wadding' which separated the cover from the foam. Some items contained plastic linings and elastic bands but there were usually only minor components within the item. Examples of the components taken from the domestic seating items are shown in Table 2.4.

Table 2.2 Summary of items sampled from sites

Site visit and code	Number of items				
	Sofas	Armchairs	Chairs	Other	Total
Site 1 (CC)	13	5	1	0	**19**
Site 2 (WF)	8	6	9	5	**28**
Site 3 (KM)	22	13	10	2	**47**
Site 4 (LC)	30	12	8	2	**52**
Site 5 (HH)	52	12	3	5	**72**
Re-use (SP)	31	17	15	1	**64**
Total	**156**	**65**	**46**	**15**	**282**

Figure 2.1 Proportion of items sampled from sites

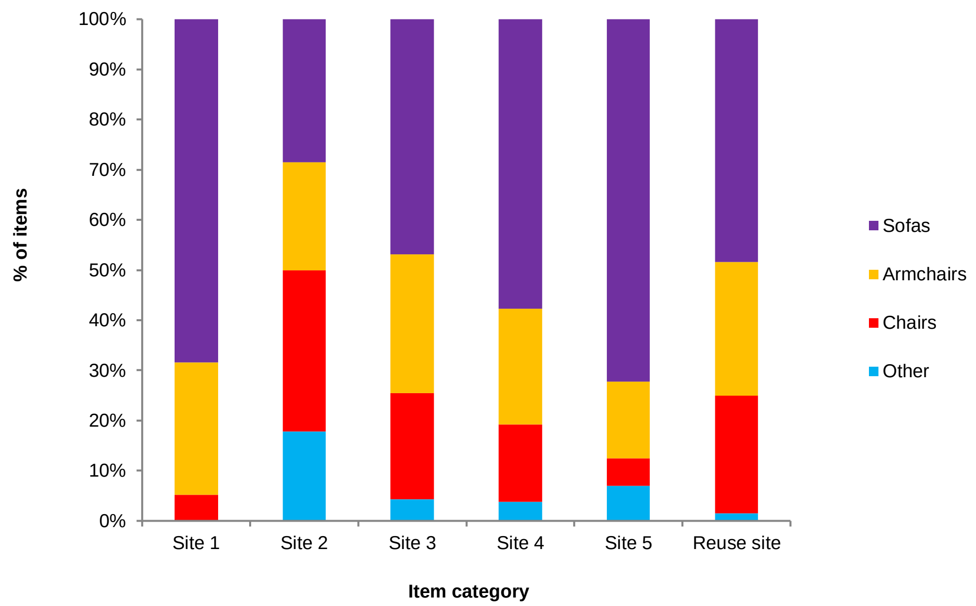
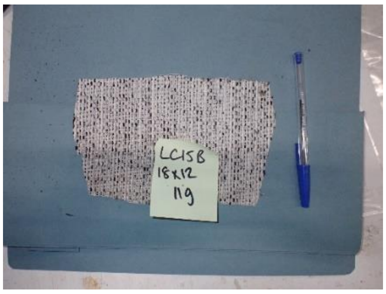


Table 2.3 Typical examples of items sampled

2-seater sofa	3-seater sofa
	
Club armchair	**Tub armchair**
	

Dining chair	Office chair
	
Footstool	**Headboard**
	

Table 2.4 Typical components in domestic seating

Cover (textile)	Cover (leather)
	
Cover (leatherette)	**Lining**
	
Foam (homogenous)	**Foam (heterogenous)**
	
Wadding	**Misc. (straps)**
	

3. Testing Approach

3.1 Tiered Approach

A three-tiered testing strategy has been adopted for this study consisting of:

i. initial screening for bromine and other metals was undertaken using a hand-held XRF device as an indication of the presence of BFRs, additives and synergists added to improve the performance of the flame retardants;

ii. use of a rapid broad screening technique to provide information on a wide range of commonly used flame retardants; and

iii. chemical extraction and semi-quantitative and quantitative analysis of PBDEs and other flame retardants identified in the screening process.

3.2 Chemical Screening Using X-ray Fluorescence

Chemical screening was undertaken to determine whether bromine was present in the sampled components. Bromine is the key indicator of BFRs as they are brominated organic compounds. XRF analysis can be used to quickly identify whether bromine is present in a sample, but the technique cannot be used to identify the specific brominated compound(s). However, XRF analysis is a good chemical screening tool to enable more focused, complex analytical testing to be used to determine the bromine compounds present.

As well as bromine the analyser was able to determine the presence of chlorine, barium, antimony, cadmium, bismuth, lead, selenium, arsenic, mercury, gold, zinc, copper, nickel, iron, chromium, vanadium and titanium. XRF is a surface analytical technique and so the concentration of the detected elements will reflect their concentration at the surface of the material.

This additional elemental analysis was able to be used to provide information about the characteristics of the samples and further information about chemical additives that were likely to have been present. For example, antimony trioxide can be added to polymers alongside BFRs as it acts as a synergist enhancing the flame retardant's performance. Therefore, where antimony was found alongside bromine there is strong evidence that the bromine was present in a BFR. The concentration of chlorine was able to be used to indicate whether a sample was likely to be composed of polyvinyl chloride (PVC), however various chlorinated flame retardants are known to exist. The presence of chromium or iron in samples were likely to be from the leather tanning process. Therefore, using chlorine, chromium and iron data helped distinguish between natural and synthetic leather (commonly PVC), although additional testing helped confirm this.

The elemental concentration was determined using a handheld XRF analyser using a programme calibrated for polymer analysis. The analyser was held against the surface of the component and the elemental composition was determined following a scan acquisition time of 30 seconds.

The MCL for POPs-classified PBDEs in waste is 1,000 mg kg^{-1}. However, for BFRs to be effective, they are normally added to materials at concentrations greater than 5% wt. (50,000 mg kg^{-1}). Therefore, functional levels of BFRs could be considered to be > 5% wt. whilst low levels would be between 0.1% wt. to 5% wt. and trace levels would be considered to be < 0.1% wt. Domestic seating textiles are not normally recycled and so if low levels or BFRs were detected it may be that these compounds could have migrated from the material or have undergone some degradation.

Several PBDE congeners[3] are classified as POPs, but most were phased out of use long before decaBDE (and c-decaBDE). tetraBDE, pentaBDE and the commercial formulation of c-octaBDE (which includes hexaBDE and heptaBDE) were given a POPs classification and subsequently banned in 2004, DecaBDE was not classified as a POP until 2019. Restrictions on HBCDD were put in place in 2014. Considering the age of the domestic seating in the waste stream, decaBDE is likely to be the most prevalent POPs-classified PBDE if present. However, it is known that decaBDE can degrade to 'lower' congeners following prolonged exposure to UV light.

Based on the results of the chemical screening, some of the textile components containing high bromine levels, indicating the presence of BFRs were selected for further laboratory testing. The selection of samples for laboratory testing was based on ensuring that there was a good cross section of source items (sofas, armchairs, etc,), components (cover, foam, linings) and material type (textiles, leather, etc,). Some of the units showed extreme wear and tear on the outer covers particularly textiles. Samples collected from units with well-worn outer covers may exhibit lower bromine due to washing and wear on the fabric.

3.3 Chemical Testing

3.3.1 Sample preparation

WRc undertook all sample preparation of samples identified for laboratory testing. Sample preparation plays a vital role in data quality and so preparing a representative sample for

[3] There are several molecular isomers of polybrominated diphenyl ethers known as congeners. The variations are due to the number and position of bromine atoms in the chemical structure. For example tetrabromodiphenyl ether contains three bromine atoms and decabromodiphenyl ether contains ten.

analysis is extremely important. WRc's on-site laboratories operate under ISO/IEC 17025:2017 and UKAS accreditation.

To prepare the samples for analysis, WRc took a representative sub-sample of each proposed cover, lining fabric or foam and ground the sample to <1 mm using step-wise particle size reduction techniques. The sample grinding was performed using cryogenic milling with liquid nitrogen. This approach was used to mitigate against the heat generated during milling of the textiles or other polymers which could lead to degradation of target compounds within the sample. Reducing the sample to a particle size of <1 mm helps to achive a high extraction efficiency of the target compounds to avoid an underestimation of concentrations present.

The prepared samples were then sent to nominated sub-contract laboratories in a cool box to limit the sample's exposure to changes in temperature. WRc kept a full audit trail of sample movements in-house and used appropriate chain of custody forms which were sent with the samples to ensure sample identity was retained.

The test facilities confirmed that UK sample preparation was acceptable, both in terms of avoiding excessive heating (which would be indicated by the smell of degraded polymers) and from the quality of the measured flame retardant fingerprints.

3.3.2 Testing laboratories

Tier 2- rapid chemical screening tests

Twenty samples were sent to VU University Amsterdam for screening.

The samples were screened for: PBDEs, HBCDD, TBBP-A, Cl-PFRs, Br-PFRs, Decabromodiphenyl ethane (DBDPE), bis-tetrabromophthalimide (EBTBP) and SCCP / MCCP (short and medium chain chlorinated paraffins).

Details of the analytical method are provided in Appendix D Section D2. Initial solvent extraction of the test samples for screening was undertaken with toluene and 2-propanol. Use of a polar solvent is usually advantageous for comprehensive PBDE extraction. However, in the case of fabric and foam samples, potentially due to the presence of high concentrations of other additives (e.g. PFR and Cl-PFRs), the addition of 2-propanol led to complete precipitation of the decaBDE from the test solution. WRc provided Amsterdam with feedback from the Tier 3 test laboratory undertaking quantitative testing who also identified initial extraction efficiency issues for the PBDE analysis to guide method refinement. Further work was undertaken by Amsterdam to refine the extraction method. It was found that use of toluene alone provided a sufficient extraction efficiency that was confirmed through quantitative testing undertaken by Eurofins. All samples were re-extracted and the data reported for decaBDE in Appendix D is on this basis.

QA measures include duplicate analysis of a number of samples, procedural blanks, use of an internal reference material (foam), and the analyses of analytical standards (SCCPs, PBDEs, HBCDD, phthalates, PFRs, TBBP-A, Cl-PFRs, and Br-PFRs). The average sample-to-sample relative standard deviations (RSDs) is less than <25 %. The limit of detection is about 0.1% of the product being analysed.

Tier 3 – semi-quantitative and quantitative testing

A total of 50 samples were submitted for quantitative testing to Fraunhofer IVV.

Initial testing focussed on PBDEs and HBCDD.

Following analysis of initial test data two further avenues of testing were pursued. The initial Fraunhofer toluene and 2-propanol extraction led to poor extraction of PBDEs in textile and foam matrices. However, following a number of method revisions a procedure using a static rather than a multi-stage automated accelerated extraction was used with toluene alone to provide a quantitative measure of PBDEs. The alternative method used a very short column, which would ensure very limited Deca-BDE degradation using a GC-quadrupole MS. The evaluation of the mass spectra also identified the presence of other flame retardants (TBBPA, phosphorus-based flame retardants). Further analyses were completed on a further 14 samples to verify this initial data.

Both the Tier 2 and 3 laboratories have world-ranking experience in testing for FRs in relevant waste matrices. However, the samples of domestic seating have proved to be particularly challenging. The presence of other flame retardant additives in textiles and foams aside from PBDEs and HBCDD have led to complications with what are proven tests. Completion of testing has required expert method revisions and revalidation by both laboratories. The data produced has been corroborated between the three laboratories involved in testing, which provides a high level of confidence in the final data, especially where we are reporting the concentration of POP classified BFRs above threshold limits. As illustrated in Section 5 in some cases where the BFRs are reactive or potentially polymeric in nature (they are integral to the polymer rather than being a surface application that can be extracted) the data may still be an underestimate of what is present in the test sample, but we are confident that there are no false positives.

3.4 Approach to Data Interpretation

XRF screening was used to understand which components in a domestic seating item were most likely to contain bromine. The laboratory analysis was used to assess whether the bromine was present as POPs-classified BFRs. When POPs-classified compounds were found, their concentration in the component was converted to their concentration in the entire item for comparison against the MCL.

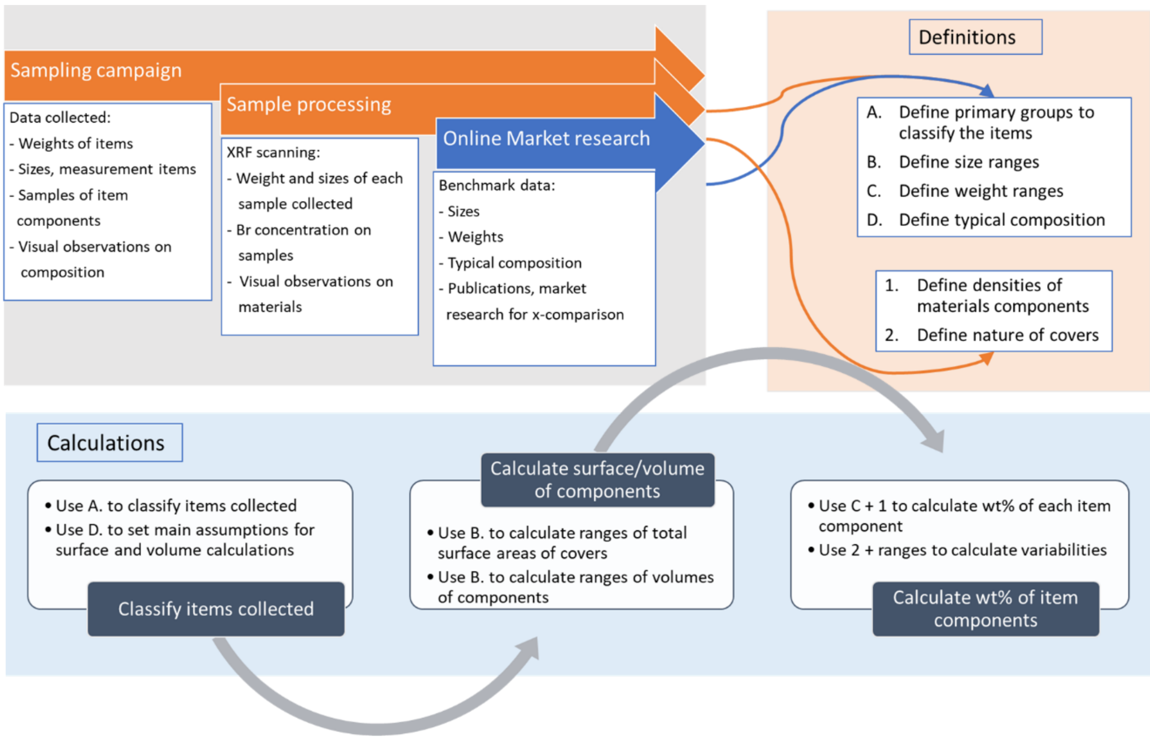
For example, if the cover of a sofa was found to have a decaBDE concentration of 10% wt., would the entire item have a decaBDE which exceeded the MCL of 0.1% wt. (1,000 mg kg^{-1}). This would determine whether the sofa should be classified as a POPs waste.

To enable the conversion from component concentration to entire item concentration, the relative weights of the cover, foam and linings in different items of domestic seating had to be determined. This determination was made using measurements taken during the sampling campaign and measurements taken from on-line research.

As it would have been complex and time consuming to completely strip each unit to measure the relative weights of all the domestic seating component items, the approach taken was to produce generic values for a range of domestic seating items which would allow the calculations to be undertaken. The on-site measurements were used to validate the findings produced by the research to generate weight proportions for each component with a margin of error. These proportions were used to recalculate the compound concentrations found in the components to determine the concentration in the entire item.

The generic data collation and calculation process is provided in Figure 3.1. Further details on the assumptions used to complete the calculation process are provided in Appendix A.

Figure 3.1 Generic data collation and calculation process



3.4.1 Standard items categories

Based on observations made during sampling and online market research the domestic seating items were grouped into the following categories into which all sampled items were placed.

- Sofas:
  - slim 2 and 3 seater;
  - padded 2 and 3 seater;
  - reclining 2 and 3 seater; and
  - 5 seater corner sofa.
- Armchair:
  - club/rolling arm;
  - wingback;
  - tub/bucket; and
  - recliner.
- Chair:
  - dining chair;
  - office chair; and
  - bar stool.

Domestic seating items are made of several components which are summarised as follows:

- the main frame that can be metallic or wooden, and in some cases a sprung base;
- the filling materials for cushions, and padding on the arms, front and back (foam and wadding);
- the outer covers (leather, leatherette or textiles); and
- lining materials that cover the bottom or back of the object and in some cases is used to cover the back of the cushions and seats. This material is often a black polymeric paper like fabric.

For each domestic seating category, the weight proportions of each of these four ‘components’ were determined which were then to be used for compound concentration conversions. The calculated proportions are presented in Appendix A alongside the methodology for their determination.

3.5 Sample Scanning and Composition Determination

All samples of the components were taken to WRc’s laboratories and scanned using an XRF analyser to determine their bromine concentration. The XRF data is presented in Section 4 and Appendix B. Alongside the scanning measurements the dimensions and weights of the components were taken. These measurements, supported by market research, were used to calculate the relative proportions of the different components in the items. This was to enable a conversion of the concentration of a parameter such as bromine or decaBDE in the component to its concentration in the entire item to aid data interpretation.

As discussed above, all the different types of domestic seating typically contained textile components including an outer cover, foam and inner linings. The items also had some sort of frame which accounted for a significant proportion of the weight of the item, especially when it was a steel frame which was typical of reclining sofas and chairs.

The composition of the different domestic seating items was calculated, and the results are provided in Table 3.1. A detailed description of the calculation methodology is provided in Appendix A. The different types of sofas and armchairs and the differences in design, material of construction among other things has resulted in the calculation of a range (maximum and minimum) of the relative proportions. This will provide a margin of error for any conversion of compound concentrations, which could be used to determine whether an item might a POPs waste beyond reasonable doubt or a possible POPs waste.

Table 3.1 Calculated composition of domestic seating items

Group	Category	Cover leather wt.%	Variation (-)	Variation (+)	Cover leatherette wt.%	Variation (-)	Variation (+)	Cover textile wt.%	Variation (-)	Variation (+)
Sofas										
2-seater	Slim	25	4.1	0.3	21	3.3	0.3	16	2.7	0.2
	Padded	22	3.9	2.9	18	3.1	2.4	14	2.6	1.8
	Recliner	22	1.8	3.1	18	1.5	2.5	12	1	1.7
3-seater	Slim	22	3.5	1.6	18	2.8	1.3	14	2.2	0.9
	Padded	25	3.5	1.6	20	2.8	1.3	16	2.2	0.9
	Recliner	20	5.7	2.5	16	4.6	2.1	11	3.1	1.4
Corner sofa (5-seater)		23	7.9	3.3	18	6.4	2.7	12	4.3	1.8
Chairs										
Armchair	Club (incl. rolled arm)	10	0.6	0.6	6	0.4	0.4	4	0.3	0.3
	Wingback	12	0.5	0.5	8	0.3	0.3	5	0.2	0.2
	Tub/Bucket	14	2.5	2.5	10	1.7	1.7	6	1	1
	Recliner	7	0.8	0.8	5	0.5	0.5	3	0.3	0.3
Chair*	Dining chair	12	1.4	1.4	10	1.2	1.2	6	0.8	0.8
	Office chair	6	2.9	2.9	5	2.4	2.4	3	1.6	1.6
Other*	Bar stool	11	4.2	4.2	9	3.4	3.4	6	2.3	2.3

*no range data is provided as these items have similar sizes and weights therefore variability is low.

4. Tier 1 – XRF screening

4.1 XRF Scanning Data

The first tier of the assessment, chemical screening using a handheld XRF analyser was primarily undertaken to determine the bromine concentration in the sampled components, as bromine is the key indicator of BFRs. As well as the bromine concentration the analyser was able to determine the concentration other elements could provide some insight into either the type of material the component was (e.g. high chlorine can be linked to PVC) or identify if specific synergists or additives have been used which can be linked to the use of a wider range of flame retardants.

Table 4.1 shows the number of items and scans undertaken for each domestic seating category. In total 985 scans were made of components taken from the sites. The summary statistics for the different component types are shown in Table 4.2.

The data obtained was similar across all sites and Figure 4.1 shows the comparison between the bromine distribution of the items scanned at the waste sites and the re-use charity. This shows that there was no difference in bromine concentration in items derived from the two different waste streams and so provides justification that the interpretations of the data produced in this work are applicable to both streams.

Table 4.1 Number of items and scans of each domestic seating category

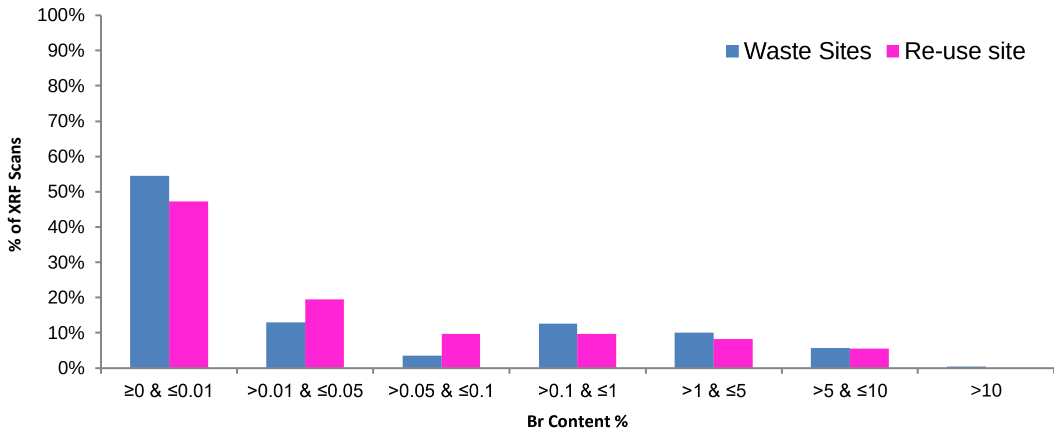
Location	Sofas		Armchairs		Chairs*		Other	
	Items	Scans	Items	Scans	Items	Scans	Items	Scans
Site 1	13	72	5	38	1	5	0	0
Site 2	8	30	6	23	9	32	5	19
Site 3	22	89	13	62	10	32	2	8
Site 4	30	114	12	53	8	25	2	8
Site 5	52	166	12	41	3	9	5	13
Re-use site	31	72	17	46	15	27	1	1
Total	**156**	**543**	**65**	**263**	**46**	**130**	**15**	**49**

Key: * Dining and office

Table 4.2 Summary of bromine concentrations found in samples across all sites

Sample type	Minimum	Average	95th %ile	Maximum	% scans >1 wt.%	Number of scans
Cover	0.00	1.66	7.89	11.5	34.8	319
Lining	0.00	0.13	0.67	4.46	1.60	250
Wadding	0.00	0.02	0.14	0.61	0.00	135
Foam	0.00	0.17	1.18	7.36	5.68	264
Misc	0.00	0.04	0.17	0.42	0.00	17

Figure 4.1 Comparison between XRF data from the waste sites and re-use site



4.2 Bromine Analysis

The distribution of bromine in the scanned components is given in Figure 4.2. The distribution is plotted by component category (covers, linings, wadding, foams, or misc.) for each item type (sofas, armchairs, chairs or other). These plots show the bromine content broken into concentration ranges and the proportion of scans for each component category that lie within each range. For example, the total proportion of scans for covers in sofas add up to 100% over each of the five concentration ranges.

The majority of scans for each of the component categories recorded bromine concentrations below functional levels (<0.1% wt.). Scans which found bromine at functional levels (i.e. >1% wt.) were mostly taken on samples of covers and foams, and the majority of such samples were taken from sofas or armchairs.

The bromine concentrations were determined at a component level, but this concentration must be converted to its concentration in the entire item for comparison against any concentration thresholds (i.e. POPs MCL). Based on the relative proportions of the components in domestic seating and if assuming all the bromine was present as decaBDE, the minimum concentrations of bromine in covers of different items are shown in Table 4.3.

Due to the greater amount of covering on a sofa, the minimum bromine concentration required for the sofa to exceed the MCL is lower than other item types. As leather has a greater density than textile and leatherette covers, the minimum bromine concentration is lower. Despite these variations it is likely that if decaBDE was present at functional levels in sofa covers the entire item should exceed the MCL. Higher concentrations of decaBDE would be required in armchairs and chairs due to their make-up, but if the compound was present at levels around 5% wt. then the item would likely be significant over the threshold beyond reasonable doubt.

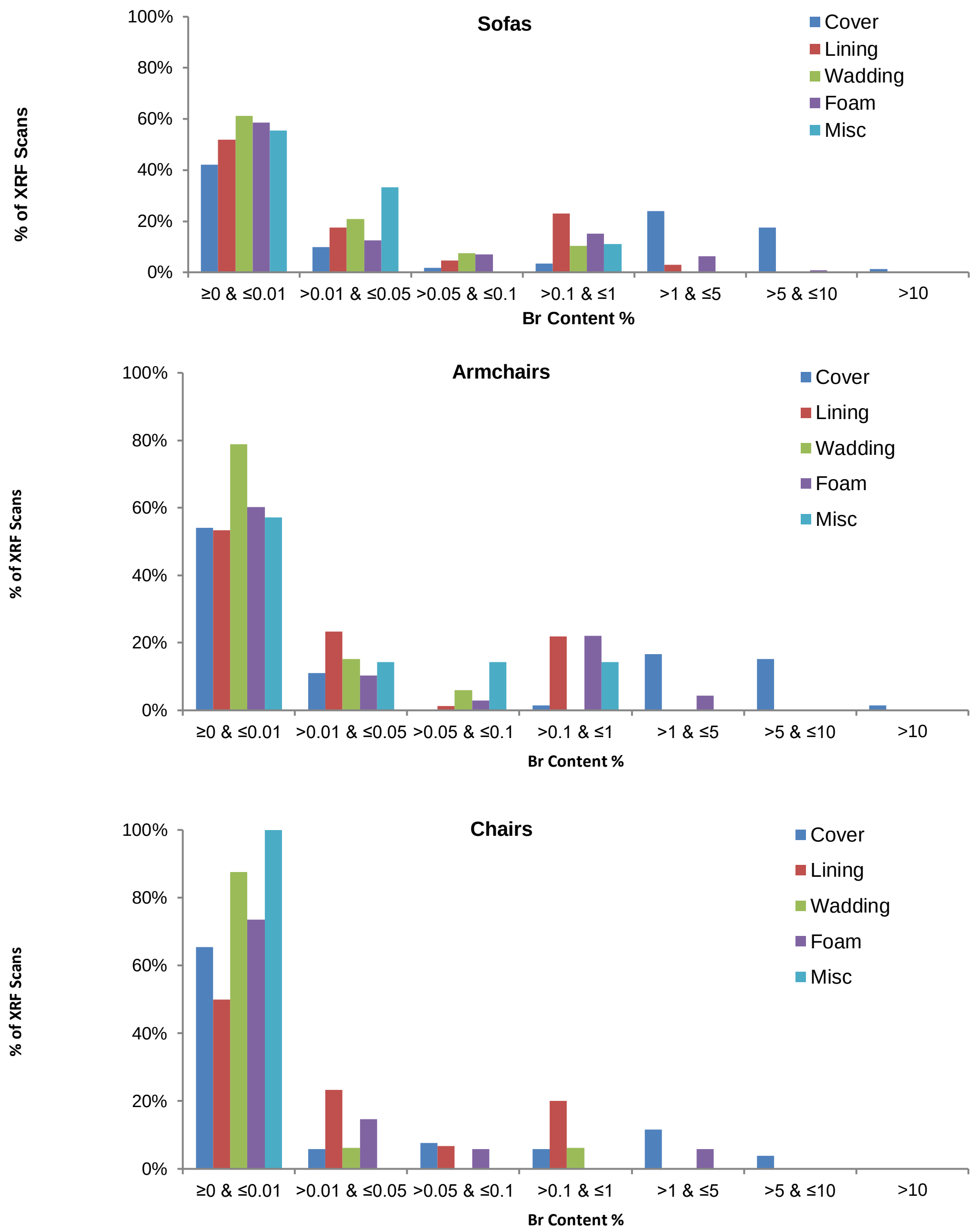
Table 4.3 Minimum bromine (assumed as decaBDE) concentration in covers which would cause an entire item to exceed POPs MCL

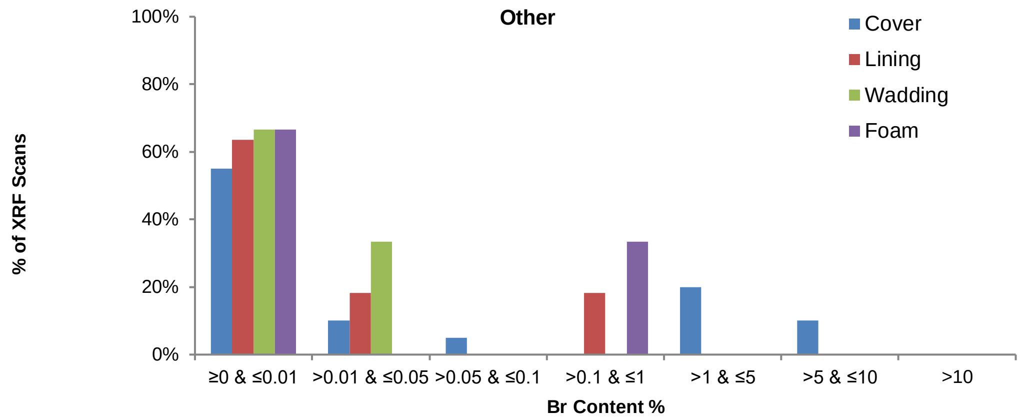
Item type	Bromine concentration in covers required for item to exceed POPs MCL (assuming bromine is present as decaBDE) mg kg^{-1}		
	Textile	Leatherette	Leather
Sofas			
2 seater ‘slim’	5,100	4,000	3,300
2 seater ‘padded’	5,400	4,200	3,700
2 seater ‘recliner’	6,400	4,200	3,500
3 seater ‘slim’	5,500	4,500	3,500
3 seater ‘padded’	5,100	4,000	3,300
3 seater ‘recliner’	6,000	4,000	3,500
5 seat corner sofa	5,100	4,500	3,500
Armchairs			
Club	19,200	12,500	8,500
Wingback	17,500	10,300	7,000
Tub/bucket	12,700	7,500	5,000
Recliner	24,000	14,000	9,000
Chairs			
Dining chair	9,900	6,800	5,800
Office chair	18,200	12,100	10,000
Bar stool	13,200	8,800	7,400
Other			
Footstool	17,000	3,900	3,800

Across the whole dataset, 75% of scans found bromine below functional levels (<0.1 wt.%), 12% of scans found bromine between 0.1% wt. and 1% wt., 8% scans found bromine between

1% wt. and 5% wt. and 5% of scans found bromine greater than 5% wt. Most scans with high bromine content were those taken on covers where 35% of scans had a bromine concentration >1% wt.. Therefore, particular focus was given to investigate the bromine distribution in covers by their material, specifically between three categories; natural leather, synthetic leather (or leatherette) and textile covers.

Figure 4.2 Distribution of bromine content by component type per item category





As outlined above the covers were the components which were most likely to contain bromine at high levels. Only 6% of foam samples were found to contain bromine greater than 1% wt. and only 3% were found to contain bromine between 0.5 and 1% wt. Where bromine was found in foams the concentration was normally between 0.05 and 0.5% wt. (18% of samples). Therefore, foams typically only contained low levels of bromine when detected.

However, for some items, such as padded sofas, the foam counts for a large proportion of the total item and so a decaBDE concentration of between 3,500 and 6,400 mg kg^{-1} would be sufficient to result in a POPs classification. It was not the case that a foam would only contain bromine if the cover did. Therefore, even if the domestic seating were not found to contain bromine in the cover, it may still be a POPs waste due to the foam.

The XRF analysis included other elements which could be used to identify the component material, such as antimony (added as antimony trioxide as a synergist with BFRs), chromium or iron (typically added to natural leathers during tanning processes[4]), chlorine (found at 36% wt. in PVC materials) and titanium (present as a whitening agent in polymers or during the tanning process to produce white leathers). These key indicators were used to inform the identification of the materials in each cover component, or where such indicators were absent from a material then further testing was required. A visual inspection was performed for cover samples where the material remained inconclusive after reviewing the XRF data. A selection of leather or leatherette cover samples were sent for further testing, Fourier-transform infrared spectroscopy (FTIR), to confirm the cover material.

Figure 4.3 shows the relationship between bromine and antimony in the domestic seating samples. Antimony is also seen present for samples with higher concentrations of bromine (which would be associated with functional levels for BFRs). Antimony trioxide is a known synergist for BFRs and a common flame-retardant formulation for textile backings was

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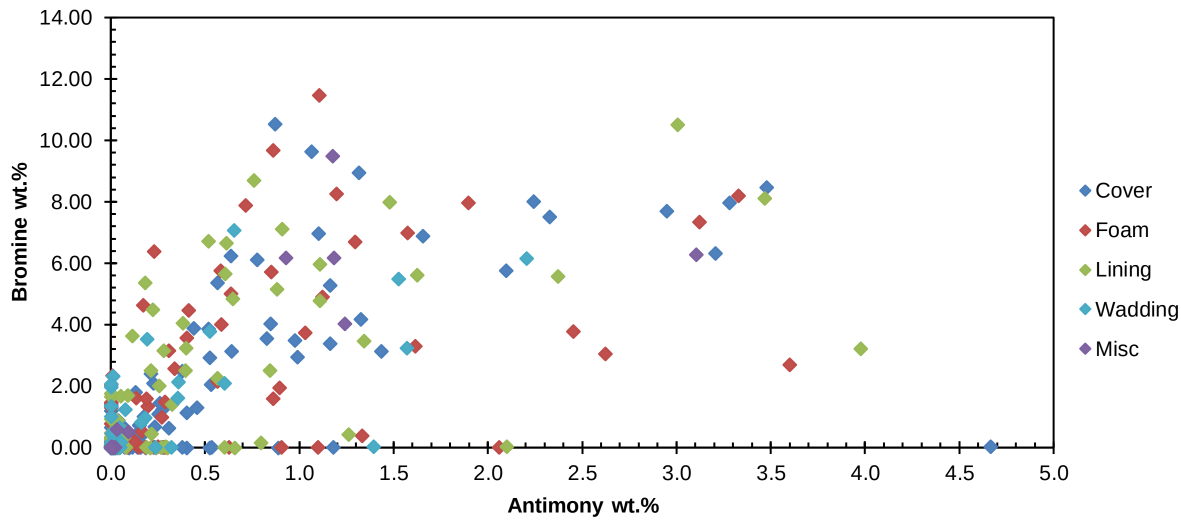
[44] Leather International Tanning with iron salts - an old system in a new light* 28 March 2004

decaBDE and antimony trioxide. Therefore, the trend showing a correlation between antimony and bromine provides a good indication that BFRs are present and possibly decaBDE. There are also examples of bromine concentrations and antimony concentrations with no presence of the other element. This also provides evidence that other types of flame retardants or chemicals are also present in the samples.

Therefore, to attempt to unpick this complexity, further analytical testing has been undertaken to try and understand whether the samples taken from domestic seating items contain other brominated compounds, or whether the interactions between other flame retardants during testing results in low-reporting of PBDE concentrations.

Figure 4.3 Antimony vs. bromine XRF comparison (by component category)

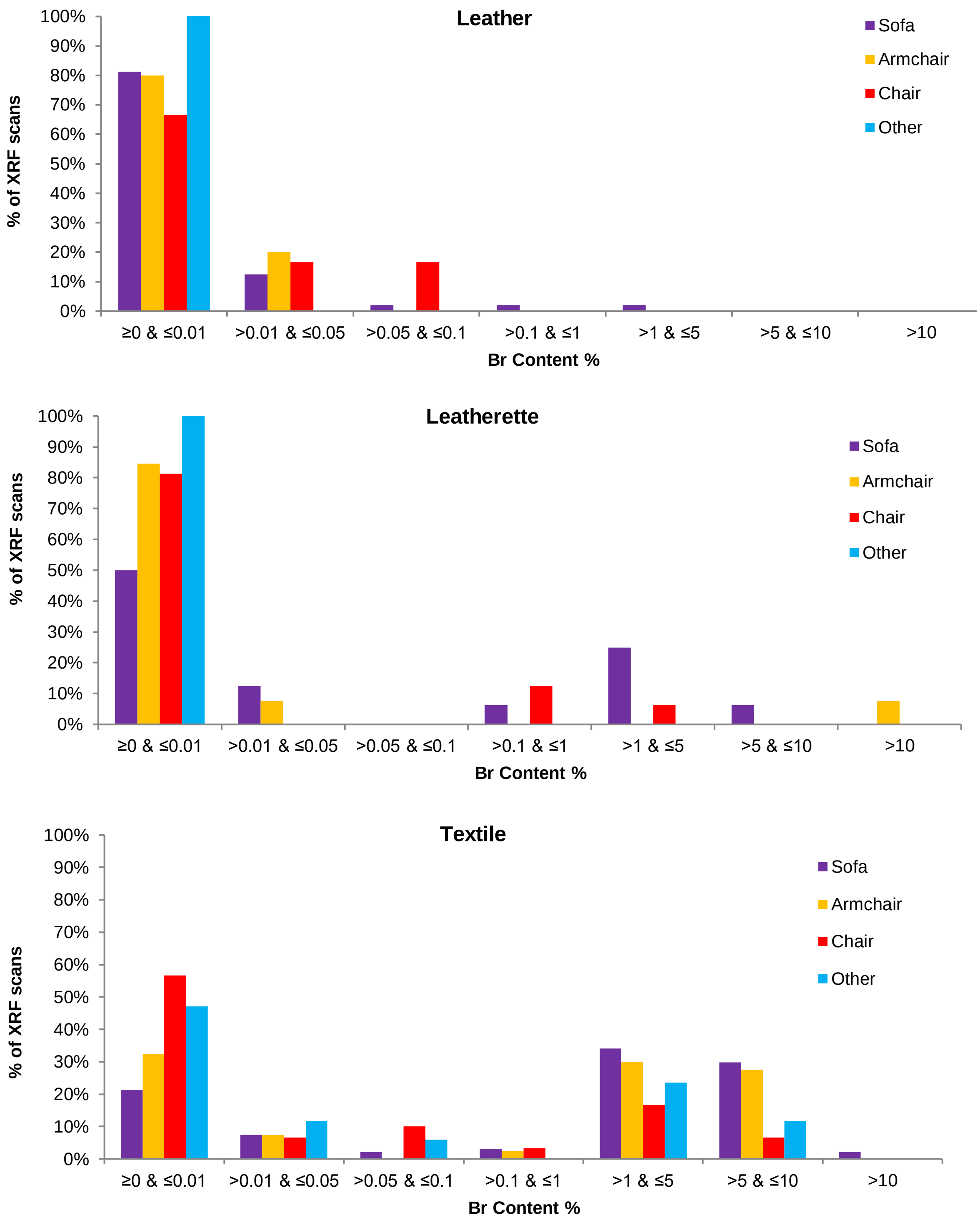


4.3 Domestic Seating Covers – Textile, Leather and Leatherette

Figure 4.4 shows the bromine distribution of leather, leatherette or textile covers plotted by item type. Only one single leather cover, 1% of the leather dataset, was found with bromine concentrations >1% wt., compared with 19% of leatherette and 54% of textile covers. Although FTIR analysis confirmed that this was a leather sample, it could be possible that it was some sort of composite.

Conversely, 97% of leather covers were found with bromine concentrations <0.1% wt, compared with 75% of leatherette covers and 43% of textile covers. In summary, most of the bromine found at functional levels using XRF analysis on domestic seating covers was found in the textile covers.

Figure 4.4 Bromine content in covers by item type per material



The XRF data has shown that there appears to be a difference between the likelihood of a synthetic leather cover containing bromine and a natural leather cover. A greater proportion of synthetic leather samples were found to contain bromine (19% of leatherette samples compared with 1%). This may be of consequence for description purposes and future management of waste domestic seating.

To differentiate between leather and leatherette samples, a combination of techniques were used. It is typical of natural leather samples to have a 'polished' outer surface and an unpolished suede-like inner surface. Conversely, leatherette samples typically have a plastic web-like backing. Therefore, visual observation of the samples was primarily used to differentiate between them. To support this the XRF data was used to identify leatherette components which were likely to be composed of polyvinyl chloride (PVC) based on the chlorine concentration being >36 wt.% (upper detection limit). Similarly, the leather samples were commonly seen to contain high concentrations of elements such as chromium or iron which are commonly used as tanning salts.

However, to provide additional data a selection of samples were sent for FTIR analysis to determine whether they were natural leather or not and if not what polymer they were made of. Table 4.4 shows the results of the analysis alongside the additional data. The results show the leatherette samples were made of a range of polymers including polypropylene, polyester and polyurethane as well as the PVC samples found via XRF. These samples are presented alongside their XRF data and the difference in the bromine content between the leatherette and natural leather samples can be seen.

4.4 Tier 1 Summary

Several conclusions can be made from the first tier of the assessment. The chemical screening has shown that brominated compounds are present in waste domestic seating in the UK. The typical composition of waste domestic seating seemed to be generally similar across the country and no difference was observed between the bromine distribution between waste domestic seating and those destined for reuse. Therefore, data collected from laboratory analysis of samples derived from waste domestic seating is relevant to items going for reuse.

Bromine was found in several components of items, but mainly in the covers, foam and linings. Little bromine was detected in other components which also only represent a small proportion of the entire item.

Table 4.4 FTIR results for selected leather/leatherette samples

Sample ID	Item origin	Bromine concentration (wt.%)	Material	Photograph
CC5-A	Sofa	3.2	Polypropylene	
CC13-A	Sofa	0.0	Leather	
HH2-A	Sofa	7.5	Polyester	
HH22-A	Sofa	3.5	Polyester	

Sample ID	Item origin	Bromine concentration (wt.%)	Material	Photograph
HH57-A	Sofa	3.9	Polyurethane	
HH64-C	Sofa	3.1	Polyurethane	
LC38-A	Sofa	0.3	Leather	
WF16-E	Sofa	3.9	Polyester	

Covers were most likely to contain bromine and just over half (54%) of textile covers contained bromine at concentrations >1% wt. However, the results showed that natural leather covers typically did not contain bromine at high levels and 97% contained <0.1% wt. of bromine. Synthetic leather or leatherette were found to contain bromine at high levels but not as often as textile covers.

In general, similar data was produced across the different domestic seating categories. For example, there was little observable difference between sofas and armchairs with similar bromine readings being detected across comparable components. A distinction was made between office and dining chairs to assess whether there was a difference between these chair types. Although the dataset for these items was substantially smaller than for sofas and armchairs, there appears to be some differences between the two categories. No high bromine levels were detected in the covers of office chairs whereas high bromine levels were detected in dining chair covers. However, similar bromine levels were found in the foams and lining of the two types of chairs which was also observed during Tier 3 testing.

Although the bromine data collected during tier 1 provides no information on the compounds of bromine present, the concentrations of bromine in many cases were characteristic of functions levels of BFRs in textiles (1-5% wt.). Additionally, there is some correlation between the concentration of bromine and antimony which provides an indication that decaBDE may be present due to the wide use of commercial decaBDE formulations with antimony trioxide. However, given that there are examples of bromine present without antimony trioxide there may be other BFRs or brominated compounds present. This gives additional emphasis on the further laboratory analysis which will be discussed in the following sections.

Although there are limitations of using XRF as a screening tool for PBDEs and HBCDD, the approach is a fast method and has highlighted the most likely components where these compounds could be added. The sampling also provided data on the relative proportions of domestic seating components. This data has shown that if PBDEs were present at 'functional' levels in either the covers or foams then this concentration is likely to cause the entire item to exceed the MCL for POPs-PBDEs.

5. Tiers 2 and 3 – Analytical Laboratory Testing

5.1 Sample Selection

The chemical screening highlighted components which are found to contain bromine at levels indicating that they could contain BFRs. Some of these samples were selected for further Tier 2 and Tier 3 analysis.

The selection of the samples was based on several factors:

- the bromine concentration;
- the type of component (cover, foam, lining);
- the source of the component (sofa, armchair, etc.);
- the material (textile, leather/leatherette); and
- matched samples (i.e. two different components from the same item).

These factors were used to produce a set of samples which encompassed the variety of item types and components which were sampled during the project. The rationale to test matched samples was included to provide an insight as to whether different types of flame retardants were present in the same item and whether it was possible that there would be some migration of flame retardants over time from the cover to the linings and foam.

The list of samples and their testing suite sent for Tier 2 and 3 analysis is shown in Table 5.1 and Table 5.2 respectively. Photographs of the samples are provided alongside their 'source items' in Appendix D.

Table 5.1 Samples sent for Tier 2 testing

WRc sample number	Code	Source item	Component	XRF Bromine (% wt.)
W9084	KM22-A	Armchair	Cover (leatherette)	11.5
W9080	KM16-A	Sofa	Cover (textile)	9.64
W9038	WF24-A	Armchair	Cover (textile)	8.94
W9176	HH56-A	Sofa	Cover (textile)	7.98
W9036	WF16-A	Sofa	Cover (leatherette)	6.88
W9020	CC17-A	Sofa	Cover (textile)	6.50

WRc sample number	Code	Source item	Component	XRF Bromine (% wt.)
W9027	CC4-B	Armchair	Cover (textile)	5.29
W9029	CC11-B	Sofa	Cover (textile)	4.06
W9025	CC27-B	Sofa	Cover (textile)	3.31
W9032	WF2-A	Dining chair	Cover (leatherette)	2.34
W9093	CC26-C	Sofa	Foam	1.97
W9034	WF6-B	Office chair	Foam	1.77
W9092	LC22-D	Sofa	Foam	1.67
W9021	CC17-B	Sofa	Foam	0.86
W9031	CC5-C	Sofa	Foam	0.61
W9082	KM17-B	Sofa	Foam	0.47
W9081	KM17-A	Sofa	Cover (textile)	6.31
W9023	CC23-B	Armchair	Cover (textile)	3.63
W9563	WF21-C	Sofa	green foam	0.006
W9564	LC17-D	Sofa	mixed colour foam	0.31

Table 5.2 Samples sent for Tier 3 testing

Sample ID	Item source	Component	XRF Bromine concentration (% wt.)
Site 1			
CC17-A	Sofa	Cover (textile)	6.50
CC17-B	Sofa	Foam	0.86
CC8-A	Armchair	Cover (textile)	6.28
CC23-B	Armchair	Cover (textile)	3.63
CC23-D	Armchair	Lining	0.88
CC27-B	Sofa	Cover (textile)	3.31
CC25-B	Sofa	Cover (textile)	4.50
CC4-B	Armchair	Cover (textile)	5.29
CC6-A	Dining chair	Cover (textile)	6.15
CC11-B	Sofa	Cover (textile)	4.06
CC8-H	Armchair	Foam	0.53
CC5-C(A)	Sofa	Foam	0.61
Site 2			
WF2-A	Dining chair	Cover (leatherette)	2.34
WF2-D	Dining chair	Lining	0.82
WF6-B	Office chair	Foam	1.77
WF16-A	Sofa	Cover (leatherette)	6.88
WF16-B	Sofa	Cover (textile)	6.99
WF16-C	Sofa	Foam	0.57
WF24-A	Armchair	Cover (textile)	8.94
WF9-A	Footstool	Cover (textile)	3.55
Site 3			
KM11-D	Other	Cover (textile)	9.86

Sample ID	Item source	Component	XRF Bromine concentration (% wt.)
KM12-E	Armchair	Lining	0.45
KM16-A	Sofa	Cover (textile)	9.64
KM17-A	Sofa	Cover (textile)	6.31
KM17-B	Sofa	Foam	0.47
KM20-C	Sofa	Foam	1.47
KM22-A	Armchair	Cover (leatherette)	11.5
KM22-B	Armchair	Cover (textile)	6.66
KM26-D	Armchair	Foam	1.67
KM37-B	Sofa	Foam	1.20
KM40-C	Sofa	Foam	1.61
Site 4			
LC15-B	Sofa	Cover (textile)	10.5
LC22-A	Sofa	Cover (textile)	8.11
LC22-D	Sofa	Foam	1.67
LC26-C	Sofa	Foam	1.97
LC7-D	Office chair	Lining	0.93
LC29-A	Sofa	Cover (leatherette)	4.03
LC33-G	Armchair	Cover (textile)	9.50
LC38-C	Sofa	Foam	1.36
LC38-D	Sofa	Foam	1.30
LC44-D	Armchair	Foam	1.35
Site 5			
HH19-A	Sofa	Cover (textile)	6.98
HH19-B	Sofa	Lining	0.31
HH2-A	Sofa	Cover (leatherette)	7.51
HH22-A	Sofa	Cover (leatherette)	3.57
HH32-C	Armchair	Foam	2.06
HH34-C	Armchair	Foam	2.07
HH51-D	Sofa	Foam	7.36
HH56-A	Sofa	Cover (textile)	7.98
HH72-A	Sofa	Cover (textile)	10.5

5.2 Tier 2 Results

The primary aim of this study was to detect POPs-classified BFRs in domestic seating. The Tier 2 analysis was used to support quantitative testing and provide information on what other compounds could also be present in the domestic seating.

In Tier 2 all samples were screened for the following determinands: PBDEs, HBCDD, TBBPA, Cl-PFRs, Br-PFRs, EBTBP, DBDPE and SCCPs / MCCPs. The analytical screening and quantitative testing are presented in Appendix D.

In summary, the Tier 2 testing has shown that other than BFRs chlorinated-PFRs and possibly other chlorinated compounds like medium chain chlorinated paraffins are present in domestic seating. Additional testing in Tier 3 also showed that chlorinated phosphorous flame retardants were present in some samples and this data is presented in Appendix D.

TCEP, TCIPP, TDCIPP, HBCB, and MCCPs have been found in some samples above or close to 0.1% wt. DecaBDE209 was found at concentrations below 0.1% wt. as well as at concentrations above 1% wt. These data, bar one sample, have been confirmed by quantitative testing undertaken by Eurofins.

SCCPs were not identified in the screening test but MCCPs were identified in one sample above 0.1% wt. and two samples at >1% wt.

5.3 Tier 3 – Semi-Quantitative and Quantitative Testing

The Tier 3 testing provides definitive evidence for the presence of POPs in domestic seating waste. Tier 3 test data is provided in Appendix D. There is a high level of confidence in the test data which was produced following method development and expansion of the test suite to identify brominated compounds that had not been accounted for by initial testing. However, the XRF test data on the extraction residues indicates that there are some samples where the bromine has not been fully recovered (illustrated in Figures 5.1 to 5.3) and it is surmised that these samples may contain Br Poly-FRs. In the majority of samples, the bromine content can be completely accounted for by the analysis undertaken. During method refinement the extractions were run on multiple systems to provide robust compound identification. During this cross-comparison an additional brominated substance identified as Decabromodiphenyl ethane was also identified in high concentrations of some samples.

5.4 Overview of Results

Both HBCDD and decaBDE have been found at percentage levels (>1% wt.) in both textile and leatherette covers. No natural leather samples were tested due to the typically low bromine concentrations found in those samples. DecaBDE has been found alongside other PBDE congeners, most commonly nonaBDE, which is typical of the commercial formulations of these flame retardants. The levels of decaBDE in textile covers were consistent across sofas, armchairs and chairs indicating that similar flame retardant formulations were used in all these textile materials.

Out of the 21 textile covers which were tested, 17 contained decaBDE or HBCDD at concentrations greater than 1% wt. equating to 81% of the samples and all but one contained decaBDE at concentrations greater than 0.1% wt. (1,000 mg kg^{-1}). During XRF scanning 54% of the textile covers were found to contain bromine at a concentration greater than 1% wt. and coupled with the PBDE analysis it appears that POPs classified PBDEs are prevalent in textile domestic seating.

Half of the leatherette samples (3 out of 6) contained decaBDE at concentrations greater than 1% wt. which is a lower proportion than the textile covers although the sample size was much smaller. A lower proportion of leatherette samples (19%) were found to contain bromine at concentrations greater than 1% wt. compared to textile covers therefore the data suggests that POPs classified BFRs are less prevalent in leatherette covers but could be present in some items.

The HBDE and PBDE results for foams and linings also showed that one foam and one lining sample contained decaBDE at percentage levels which is a lower proportion than what was seen in the cover samples. This could be partially explained by the typically lower bromine concentration which were observed in foams and linings from the XRF scanning. One foam sample contained tetraBDE and pentaBDE which are characteristic of commercial pentaBDE formulations which probably reflects the age of the item.

5.4.1 Comparison against POPs thresholds

The decaBDE concentrations found in the covers of the domestic seating samples sent for Tier 3 testing were compared with the minimum decaBDE concentrations required in the covers for the entire item to be classified as a POPs waste. The comparison is shown in Table 5.3 where the POPs threshold is the calculated value based on the total weight of the item. For sofas, either textile or leather, the minimum decaBDE concentration is approximately 0.4 – 0.8% wt. All the sofa covers which were found to contain decaBDE exceeding this limit had concentrations significantly greater than this value between 4 and 20% wt. Therefore, the items from which these covers were sourced would be classified as POPs wastes beyond reasonable doubt and 76% of textile covers tested had a decaBDE concentration exceeding the limit. However, one sample which did not exceed this limit had a HBCDD concentration of 79,739 mg kg^{-1} (7.97% wt.), which would also mean the source sofa would also be a POPs waste. Therefore, 81% of the textile covers sent for Tier 3 testing contained POPs at concentrations high enough for the entire sofa to be classified as a POPs waste.

A lower proportion of leatherette sofas were found to contain POPs in the covers which would result in a POPs classification (25%), but that may be due to the smaller sample size than the textile covers. Similar proportions were recorded for the textile and leatherette armchairs and chairs (89% and 100%) respectively although only two leatherette samples were tested.

The results show that POPs-classified BFRs (predominately decaBDE) are present in a significant proportion of textile and leatherette domestic seating above the POPs threshold.

Table 5.3 DecaBDE concentrations found in covers compared with the minimum decaBDE concentration required in a cover for a POPs classification

Component type	Minimum decaBDE concentration for POPs classification (mg kg^{-1})	Range of decaBDE found in items (mg kg^{-1})	% of samples exceeding POPs classification due to decaBDE	Total number of samples tested
Textile sofa	4,200 – 7,680	696 – 204,245	75%	12
Leatherette sofa	4,800 – 5,400	859 – 45,883	25%	4
Textile armchairs and chairs	11,880 – 28,800	3,221 – 118,050	89%	9
Leatherette armchairs and chairs	8,890 – 16,800	44,257 – 137,212	100%	2

5.4.2 Bromine accountability

The HBCDD and PBDE results were compared with XRF data to determine the bromine mass balance or 'bromine accountability' for each of the samples during the analysis. For some samples the concentrations of HBCDD and/or PBDEs were shown to account to the total amount of bromine detected by XRF. However, for other samples there is a 'bromine gap' which means a proportion of the bromine present in the samples has not been accounted for. Two possible explanations for the bromine gap are:

- extraction issues during the analytical testing for some samples have resulted in an under-reporting of the HBCDD or PBDE data; or

- other brominated compounds are present in the samples which have not been detected or cannot be extracted due to their specific chemistry. For example, reactive brominated flame retardants bound to the polymer are not likely to be extracted during testing.

Additional testing was undertaken to determine whether other brominated flame retardants were present in the some of the samples. The testing focused on the following brominated flame retardants:

- tetrabromobisphenol A (TBBPA);

- 1,2-bis(tribromophenoxy)-ethane (TBPE); and

- decabromodiphenyl ethane (DBDPE).

Neither TBBPA nor TBPE were found in any of the samples in concentrations greater than trace amounts. However, for some samples DBDPE was confirmed to be present at percentage levels which has been assumed to account for the 'missing' bromine in those samples although quantitative testing would be required to confirm this.

Plots showing the 'bromine accountability' for each of the samples tested are shown in Figure 5.1 to Figure 5.3. In general, the bromine accountability for the textile samples is good with the majority being shown to contain decaBDE. Two samples were shown to contain DBDPE, and only two samples had a significant amount of 'missing bromine'. Based on the results of the other samples it is possible that the low results of these two samples is questionable. For the other materials significantly more samples contain 'missing bromine' which may indicate that those samples could contain other types of brominated compounds. This may be particularly true for foams were brominated-polymers are known to have been used in expanded polystyrene. However, it may also be the case that the test matrix caused issues with the extraction technique employed for this analysis.

Figure 5.1 Bromine accountability for textile cover samples

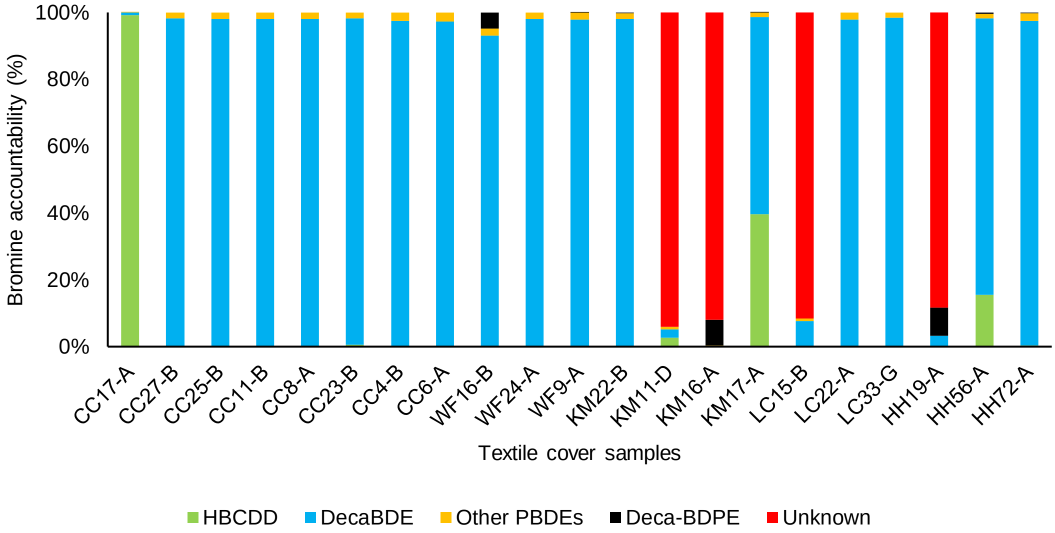


Figure 5.2 Bromine accountability for leatherette cover samples

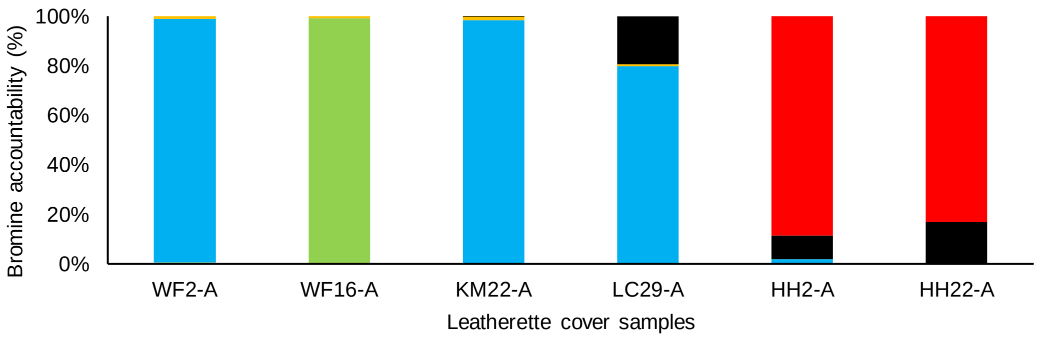
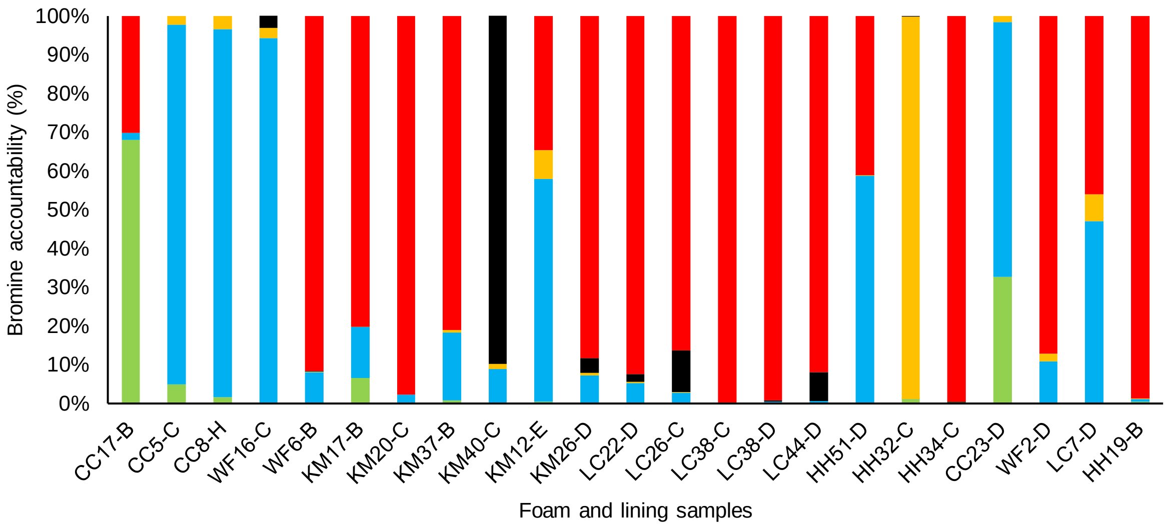


Figure 5.3 Bromine accountability for foam and lining samples



5.5 Summary of Tier 3 Testing

The results of the Tier 3 analysis showed that POPs-classified PBDEs and HBCDD were present in the samples analysed. DecaBDE was commonly found at percentage levels in textile covers and also in some leatherette covers. DecaBDE was found in one foam and one lining sample above 1% wt., but the concentrations found in the covers far outweighed those found in the other components.

The concentrations of decaBDE and HBCDD in the covers were consistently found at levels which would result in a POPs classification of the entire item. This was true for sofas, armchairs and chairs. The concentrations found in textile covers in particular were significantly above the 'minimum' concentration required for the entire item to be classified as a POPs waste. Therefore, even accounting for analytical challenges, the items which the components were sourced would be classified as POPs wastes beyond reasonable doubt.

For some of the samples not all the bromine determined via XRF could be accounted for by HBCDD and PBDE detected during the testing. Although in some cases other brominated flame retardants were identified and shown to be present, there was still a significant amount of 'missing bromine'. It is possible that some of the missing bromine could be present as other compounds such as brominated-polymers in foams, but it is also possible that the HBCDD or PBDE concentrations were under-reported due to limitations of the extraction technique.

The Tier 2 testing supported the data obtained during Tier 3, but also indicated that some samples contained other chemicals such as chlorinated PFRs and medium chained chlorinated paraffins. The analytical laboratory reported that in some cases the presence of these compounds can interfere with the testing for brominated flame retardants if they were unexpectedly present. This emphasises that the analytical testing for flame retardants is complex and can result in difficulties during analysis.

Nevertheless, despite some challenges in testing for some of the samples, the results show that POP-classified BFRs can be present in a significant number of domestic seating in the UK.

The Tier 3 analysis data for textile and leatherette covers are shown in Table 5.4 and the data for foam and lining samples are shown in Table 5.5. The text presented in black were derived from GC-HRMS for the PBDEs and HPLC-MS for HBCDD. The results which are highlighted in orange were verified by GC-ECD analysis.

Table 5.4 HBCDD, PBDE and deca-BDPE concentrations in textile and leatherette 'cover' samples

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
Textile covers											
CC17-A	Sofa	92,997	0.98	n.d. (<0.24)	n.d. (<0.92)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<40.6)	n.d. (<18.4)	696	n.d. (<10.0)
CC27-B	Sofa	45	n.d. (<0.41)	n.d. (<0.26)	1	1	8	210	1,841	114,234	n.d. (<10.0)
CC25-B	Sofa	n.d. (<10.0)	n.d. (<0.57)	n.d. (<0.39)	2	3	24	277	2,006	121,472	n.d. (<10.0)
CC11-B	Sofa	n.d. (<10.0)	n.d. (<0.57)	n.d. (<0.18)	n.d. (<0.70)	1	12	171	1,754	97,951	n.d. (<10.0)
CC8-A	Armchair	161	n.d. (<0.33)	n.d. (<0.24)	n.d. (<1.08)	1	21	204	1,498	82,889	n.d. (<10.0)
CC23-B	Armchair	414	n.d. (<0.38)	n.d. (<0.20)	n.d. (<1.42)	n.d. (<0.51)	6	140	1,180	75,195	n.d. (<10.0
CC4-B	Armchair	n.d. (<10.0)	n.d. (<0.5)	0.4	1	1	4	207	1,666	71,890	n.d. (<10.0)
CC6-A	Dining chair	n.d. (<10.0)	n.d. (<0.5)	0.4	1	1	7	205	2,330	93,198	n.d. (<10.0)
WF16-B	Sofa	n.d. (<10.0)	n.d. (<0.59)	0.5	1	1	5	238	1,942	98,857	5,229
WF24-A	Armchair	n.d. (<10.0)	n.d. (<0.28)	0.3	1	2	15	273	2,174	118,050	n.d. (<10.0)
WF9-A	Footstool	n.d. (<10.0)	n.d. (<0.26)	n.d. (<0.17)	n.d. (<0.66)	1	12	203	1,195	65,305	77
KM22-B	Armchair	44	n.d. (<0.03)	n.d. (<0.05)	0.8	1	13	157	1,489	90,536	178
KM11-D	Footstool	2,352	0.2	0.2	3	6	41	483	165	2,285	n.d*
KM16-A	Sofa	48	n.d. (<0.03)	n.d. (<0.05)	0.1	0.6	1	11	23	217	7,387

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
KM17-A	Sofa	29,149	n.d. (<0.03)	n.d. (<0.05)	0.8	n.d. (<0.51)	3	126	886	43,398	11
LC15-B	Sofa	58	n.d. (<0.04)	n.d. (<0.07)	1	5	34	516	241	6,333	n.d.*
LC22-A	Sofa	8	n.d. (<0.03)	0.22	1	1	7	209	1,349	68,286	n.d. (<10.0)
LC33-G	Armchair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	1	1	8	111	1,502	97,951	n.d.
HH19-A	Sofa	119	n.d. (<0.26)	n.d. (<0.17)	n.d. (<0.57)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<0.51)	n.d. (<28.8)	2,929	7,598
HH56-A	Sofa	15,195	n.d. (<6.13)	n.d. (<0.31)	2	1	7	164	1,141	81,267	499
HH72-A	Sofa	699	n.d. (<1.70	n.d. (<0.31)	n.d. (<1.50)	1	3	319	4,325	204,245	576
Leatherette covers											
WF2-A	Dining chair	289	0.6	0.6	n.d. (<1.52)	2	12	103	426	44,257	n.d. (<10.0)
WF16-A	Sofa	18,959	n.d. (<0.35)	n.d. (<0.21)	n.d. (<1.08)	0.5	6	133	n.d. (<22.1)	n.d. (<859)	n.d.*
KM22-A	Armchair	n.d. (<10.0)	0.04	n.d. (<0.05)	0.9	1	12	185	1,969	137,212	264
LC29-A	Sofa	53	n.d. (<0.05)	n.d. (<0.05)	0.3	n.d. (<0.51)	4	62	391	45,883	11,227
HH2-A	Sofa	128	n.d. (<0.53)	n.d. (<0.31)	n.d. (<1.19)	n.d. (<0.51)	n.d. (<1.01)	26	16	1,548	8,142
HH22-A	Sofa	n.d. (<10.0)	n.d. (<0.46)	n.d. (<0.31)	n.d. (<0.96)	n.d. (<0.51)	n.d. (<1.01)	33	n.d. (<14.2)	n.d. (<1,023)	6,224

Table 5.5 HBCDD, PBDE and deca-BDPE concentrations in foam and lining samples

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
Foams											
CC17-B	Sofa	1,027	n.d. (<0.43)	n.d. (<0.24)	n.d. (<1.53)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<21.1)	n.d. (<15.1)	28	n.d. (<10.0)
CC5-C	Sofa	562	0.3	n.d. (<0.14)	n.d. (<0.59)	n.d. (<0.51)	2	77	183	10,563	n.d. (<10.0)
CC8-H	Armchair	53	n.d. (<0.23)	n.d. (<0.14)	n.d. (<0.59)	n.d. (<0.51)	3	56	56	3,186	n.d. (<10.0)
WF16-C	Sofa	n.d. (<10.0)	n.d. (<0.42)	n.d. (<0.26)	n.d. (<0.5)	n.d. (<0.51)	n.d. (<1.01)	33	85	4,240	137
WF6-B	Office chair	16	n.d. (<0.41)	n.d. (<0.21)	n.d. (<1.00)	n.d. (<0.51)	1	37	n.d. (<27.0)	1,820	30
KM17-B	Sofa	429	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	n.d. (<1.01)	n.d. (<43.0)	n.d. (<35.0)	871	n.d. (<10.0)
KM20-C	Sofa	39	n.d. (<0.03)	n.d. (<0.05)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<18.4)	n.a. (<17.0)	385	n.d. (<10.0)
KM37-B	Sofa	148	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	3	50	72	3,099	n.d. (<10.0)
KM40-C	Sofa	9	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	1	31	23	363	3,760
KM12-E	Armchair	52	0.1	0.1	1	9	27	488	434	7,404	n.d.*
KM26-D	Armchair	25	n.d. (<0.03)	n.d. (<0.05)	0.1	0.6	1	36	45	1,099	587
LC22-D	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	0.1	n.d. (<0.51)	n.d. (<1.01)	34	28	967	338
LC26-C	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	1	41	18	802	3,112
LC38-C	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<39.2)	n.d. (<16.3)	n.d. (<713)	n.d. (<100)

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
LC38-D	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<36.4)	n.d. (<18.1)	74	73
LC44-D	Armchair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.06)	n.d. (<0.05)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<34.1)	n.d. (<20.4)	133	1,369
HH51-D	Sofa	n.d. (<10.0)	n.d. (<6.33)	6	n.d. (<0.99)	1	11	228	19	134,311	127
HH32-C	Armchair	315	11,686	17,478	n.d. (<0.96)	n.d. (<0.51)	n.d. (<1.01)	50	n.d. (<30.3)	36	44
HH34-C	Armchair	n.d. (<10.0)	n.d. (<49.17)	n.d. (<0.31)	n.d. (<0.99)	n.d. (<0.51)	n.d. (<1.01)	14	n.d. (<18.5)	61	44
Linings											
CC23-D	Armchair	6,085	n.d. (<0.20)	n.d. (<0.34)	n.d. (<1.08)	1	5	122	159	12,215	n.d. (<10.0)
WF2-D	Dining chair	16	n.d. (<0.41)	n.d. (<0.22)	n.d. (<0.69)	1	7	263	52	1,739	n.d.*
LC7-D	Office chair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	0.1	5	23	531	290	5,736	n.d.*
HH19-B	Sofa	396	n.d. (<0.26)	n.d. (<0.26)	n.d. (<0.90)	n.d. (<0.51)	2	177	n.d. (<29.0)	390	n.d.*

n.d. – not detected (detection limit in brackets)

n.d.* not detected, extraction was performed with polar solvent which may have resulted in underestimated results

6. Summary of Findings and Conclusions

A significant amount of information which can be used to inform the future classification of UK domestic seating has been collected as part of this Environment Agency led study. At the present time we are still awaiting the quantitative analytical test data, but a number of preliminary conclusions can be made.

1. **Sample collection:** The sampling programme carried out at two HWRCs, two waste transfer stations, a reception hall taking bulky waste at an EfW facility and one re-use charity warehouse and shop has produced a robust dataset which is considered to be representative of waste domestic seating produced within the UK. Although the site visits were undertaken during Covid-19 restrictions, discussions with site personnel confirmed the waste stream to be typical of the cross section of the type and cross-section of items received at each site during routine operations. All sites received their waste from a wide catchment area across their respective counties covering a range of demographics providing confidence that the samples obtain were representative of the UK waste stream as a whole.

2. **The sample:** A total of 282 items of soft furniture were sampled in November 2020. Sample collection was weighted towards sofas and armchairs as these represent the highest proportion of item types in the UK waste stream. At the first three sites each item or unit of furniture was the weighed and accurate dimensions of the units recorded to allow quantification of the weight of the covers, linings, and foam to be calculated as a percentage of the whole unit using a calculated surface area and measured density data. Samples were collected from all textile or foam components within the unit and included: outer covers (textile, leather and synthetic leather / leatherette), under-covers, cushions base linings, unit base linings, frame covers, foam layers and webbing. Samples were given unique identifiers and taken to the WRc waste laboratory for XRF screening ahead of a sub-sample being selected for analytical testing.

3. **Target compounds:** Flame retardants can be added to textiles in a number of ways. Reactive flame retardants are added during the polymerisation process and become an integral part of the polymer and form a co-polymer. The result is a modified polymer with flame retardant properties and different molecule structure compared to the original polymer molecule. Additive flame retardants, which include PBDEs, are incorporated into the polymer prior to, during, or more frequently after polymerisation as a coating. Additive flame retardants are monomer molecules that are not chemically bounded to the polymer. They are commonly added with metal oxide synergists to improve their performance. They may therefore, in contrast to reactive flame retardants, be released from the polymer during normal use and thereby also discharged to the environment. In contrast to most additives, chemical flame retardants can appreciably impair the properties of polymers. The basic problem is the trade-off between the decrease in

performance of the polymer caused by the flame retardant and the fire retardancy requirements. In the case of fabrics that are designated as "flame retardant," that have been topically treated with chemicals, the flame retardancy of the fabric will dissipate over time, particularly with repeated cleaning and at end of life they may no longer contain functional levels of flame retardants. In this study the target compounds were PBDEs and HBCDD which are additive flame retardants. However, by screening for bromine, it is possible that other flame retardants have been detected, such as TBBPA, which is a reactive type. To address this issue a tired testing regime was adopted to assess for PBDEs and HBCDD in the domestic seating waste.

4. **Test regime:** A three-tiered testing strategy was adopted for domestic seating testing consisting of:

   i. initial screening for bromine and other metals (as an indication of the presence of BFRs and synergists added to improve the performance of the FRs) using a hand-held XRF device (282 samples);

   ii. use of a broad screening technique to provide information on a wide range of commonly used FR's (20 samples); and

   iii. testing of a chemical extraction and quantitative analysis of PBDEs congeners and HBCDD (50 samples) and other flame retardants (14 samples for selected PFRs and TBBPA).

5. **XRF data analysis:** The XRF data showed no differences between samples collected at the different sites for both the waste sites and the re-use charity. This indicates that the composition of waste domestic seating is consistent across the country and the data can be taken to be a good representation of that composition. The majority of scans for each of the component categories recorded bromine concentrations below functional levels (<0.1% wt.). Scans which found bromine at functional levels (i.e. >1% wt.) were mostly recorded on samples of covers and foams, and the majority of such samples were taken from sofas or armchairs. Only 1% of leather covers (a single sample) were found with bromine concentrations >1% wt., compared with 19% of leatherette and 54% of textile covers. Leather and leatherette covers were identified by a combination of dismantling (looking at both sides of the cover) and chemical testing. Leather items were usually identified by a polished outer surface and suede, unpolished inner surface. However, for some items chemical testing was required to determine the material. The chemical testing revealed that a range of polymer types are used to make synthetic leather covers. Only 6% of foam samples were found to contain bromine greater than 1% wt. and only 3% were found to contain bromine between 0.5 and 1% wt.. Where bromine was found in foams the concentration was normally between 0.05 and 0.5% wt. (18% of samples). The bromine concentrations were determined at a component level, but this concentration must be converted to its concentration in the entire item for comparison against any concentration thresholds (i.e. POPs MCL). Due to the greater amount of covering on a sofa, the minimum bromine concentration

required for the sofa to exceed the MCL is lower than other item types. As leather has a greater weight than textile and leatherette covers, the minimum bromine concentration is lower. Despite the variations it is likely that if decaBDE was present at functional levels in sofa covers the entire item should exceed the MCL. Higher concentrations of decaBDE would be required in armchairs and chairs due to their make-up, but if the compound was present at levels around 5% then the item would likely be significantly over the POPs MCL. A summary of the XRF scanning results is shown in Table 6.1 and this shows the total number of scans done and the percentage which recorded a bromine content >1% wt.. This provides an indication on the proportion of the samples which are suspected of containing BFRs at functional levels.

6. **Chemical tests:** Despite some difficulties experienced during analytical testing, these challenges have been overcome by the expertise of the test laboratories. The available data shows a high level of comparability between three laboratories and although there are a few inconsistencies we can therefore be confident that the study has shown beyond reasonable doubt that the concentration of POPs in domestic seating exceeds thresholds although the accuracy of definitive concentrations is subject to some error. The data does indicate that testing these types of matrices is extremely difficult and application of standard methods may not be sufficient. Technical expertise in this instance has been used to overcome a variety of complex analytical issues to generate a robust dataset to support regulatory decision making.

   Chemical analyses have shown that POPs classified PBDEs and HBCDD are present in some domestic seating in the UK at concentrations which would result in a POPs classification. DecaBDE was the most common POPs-classified compound found in samples and was consistently found at percentage levels in textile covers as well as in some leatherette covers. One foam and one lining sample also contained decaBDE above 1% wt.. HBCDD was found in a small number of samples at high percentage levels which would also result in a POPs classification. The chemical testing combined with the XRF data showed that for textile domestic seating bromine is present in a large proportion of the waste stream and it is likely that the bromine is present as decaBDE. Although other brominated flame retardants were found, for example DBDPE, these compounds are not considered to currently be common in the waste stream. DBDPE was used as a replacement for decaBDE and so may become more prevalent in waste over time. DBDPE is not currently classified as a POP, but it is currently under REACH assessment for its bio-persistence. However, some of the ‘missing bromine’ reported in the analysis may be due to under-reporting due to analytical difficulties particularly during the extraction stage of the analysis. Additional testing also identified that chlorinated PFRs are present in some of the domestic seating samples and although these chemicals also not currently POPs they may become a concern in the future. A summary of the Tier 3 testing is provided in Table 6.2. This shows the proportion of the samples tested with high levels of POPs-classified brominated flame retardants (>1% wt.).

7. **Estimation of POPs in UK waste domestic seating:** Based on the results of the XRF analysis and Tier 3 chemical testing the amount of POPs-classified BFRs in waste domestic seating could be estimated. The methodology for the calculations is provided in Appendix E. Based on these calculations, there is an estimation of between 364 and 476 tonnes of POPs-classified BFRs per 100,000 tonnes of waste domestic seating in the UK. Although some of these POPs may be present as HBCDD and some older PBDEs, the majority would be expected to be decaBDE. Textile covers from sofas accounted for 88% of the amount of POPs-classified brominated flame retardants and when combined with textile covers from armchairs, accounted for 94% of the total.

Table 6.1 Summary of XRF scanning results

Sample type	Number of scans	% with bromine over 1% wt.
Sofas		
Textile cover	94	66%
Leather cover	47	2%
Leatherette cover	32	31%
Foam	147	6%
Lining	134	3%
Wadding	78	0%
Armchairs		
Textile cover	40	58%
Leather cover	20	0%
Leatherette cover	13	8%
Foam	72	6%
Lining	74	0%
Wadding	35	0%
Chairs – Office		
Textile cover	11	0%
Leather cover	1	0%
Leatherette cover	6	0%
Foam	15	7%
Lining	11	0%
Wadding	4	0%
Chairs – Dining		
Textile cover	19	37%
Leather cover	5	0%
Leatherette cover	10	10%
Foam	18	0%
Lining	19	0%
Wadding	12	0%

Sample type	Number of scans	% with bromine over 1% wt.
Other		
Textile cover	17	35%
Leather cover	2	0%
Leatherette cover	2	0%
Foam	12	8%
Lining	12	0%
Wadding	6	0%

Table 6.2 Summary of Tier 3 testing results

Sample type	Number of samples tested	% of sample with HBCDD or POPs classified PBDEs >1% wt.
Sofas		
Textile covers	12	75%
Leatherette covers	4	25%
Leather covers	0	-
Foams	12	17%
Linings	1	0%
Armchairs		
Textile covers	6	100%
Leatherette covers	1	100%
Leather covers	0	-
Foams	5	20%
Linings	2	50%
Chairs		
Textile covers (Dining chair)	1	100%
Leatherette covers (Dining chair)	1	100%
Leather covers	0	-
Foams	1	0%
Linings	2	0%
Other		
Textile covers	2 (footstools)	50%
Leatherette covers	0	-
Leather covers	0	-
Foams	0	-
Linings	0	-

References

Benkhaya, S., M'rabet, S. and El Harfi, A. (2020) 'Classifications, properties, recent synthesis and applications of azo dyes', *Heliyon*. Elsevier, 6(1), pp. e03271–e03271. doi: 10.1016/j.heliyon.2020.e03271.

Dhungana, B. *et al.* (2019) 'Abundances and concentrations of brominated azo dyes detected in indoor dust', *Environmental Pollution*, 252, pp. 784–793. doi: https://doi.org/10.1016/j.envpol.2019.05.153.

Peng, H. *et al.* (2016) 'Mutagenic Azo Dyes, Rather Than Flame Retardants, Are the Predominant Brominated Compounds in House Dust', *Environmental Science & Technology*. American Chemical Society, 50(23), pp. 12669–12677. doi: 10.1021/acs.est.6b03954.

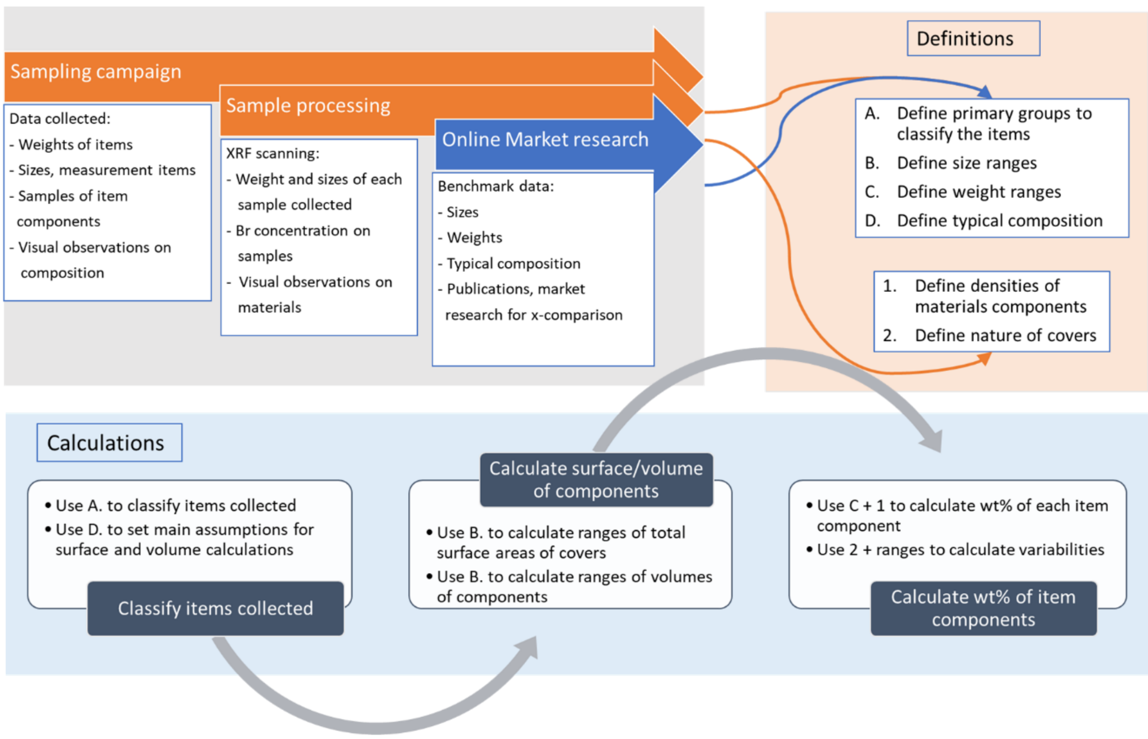
Appendix A Data Collation and Calculation of Component Proportions in Domestic Seating Units

A1 Approach

During the domestic seating sampling campaign, the sampled units have been allocated into a discrete number of groups based on detailed physical measurements completed on site and then benchmarked with on-line product dimensions to provide a compatibility check. Both site measurements and manufacturers data were used to determine the relative proportions (by either surface area or volume) of the different components within a unit (covers, foams etc.) taking into account their thickness and weight / density in each domestic seating unit. This information has then been used to back calculate XRF bromine and POPs testing data on a component level to the proportion in the overall unit for comparison against relevant thresholds.

The data collection and calculation processes are outlined in Figure A.1.

Figure A.1 Generic data collation and calculation process



Each of the calculation steps and assumptions used in this report are explained in the following section. Where appropriate natural variability between domestic seating items from different manufacturers in terms of the frame design, fabrics and construction has been taken into account by producing range data for each measurement criteria.

A2 Data Collation

A2.1 Domestic seating categories

For ease of comparison the domestic seating items sampled have been grouped as follows:

- sofas;
- armchairs (part of a suite or individual chairs);
- chairs (dining, office); and
- others (footstools, headboards, children's' furniture and bean bags, etc.).

Each main group has then been sub-divided into 'categories' and all items sampled in the field sampling programme have been allocated to a category as listed in Table A.1. In some cases the group or category has been estimated based on available seating cushions and side pieces as the base frame was not always present, in these cases the sizes of the available pieces were used to identify a potential source item.

Table A.1 Number of items of soft-furnishings by group and category

Group	Category	Items (No.)	%
Armchairs	Club (incl. rolled arm)	36	14%
	Wingback	9	3%
	Tub/Bucket	7	3%
	Recliner	5	2%
Chairs	Dining chair	21	8%
	Office chair	17	7%
	Bar stool	4	2%
Sofas	2-seater slim textile	40	15%
	2-seater slim leather	14	5%
	2-seater padded textile	14	5%
	2-seater padded leather	27	10%
	2-seater recliner	9	3%
	3-seater slim textile	11	4%
	3-seater slim leather	5	2%
	3-seater padded textile	4	2%
	3-seater padded leather	7	3%
	3-seater recliner	6	2%
	corner sofa 5 seats recliner (at LC slim)	9	3%
Others	Footstools/ headboards /children's furniture/bean-bags and a futon	6	2%

A2.2 Item composition

Most soft-furnishing items are made up of a combination of components:

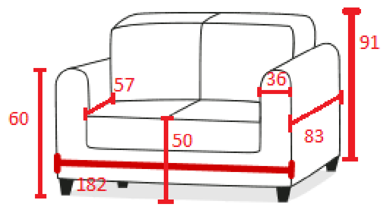
- the main frame that is made of metal or wood;
- webbing under the seats and in some cases springs in older and more top-end units;
- polymer foams used in the seat and back as dense filling materials present in a range of colours, densities and thickness;
- thin foam layer found on arm cover and more generally over the frame;
- polyester or cotton wadding that was commonly found between the outer cover and lining and the main foam seat or padded back;
- covers (outer and inner) on the frame and cushion covers which included real leather, synthetic leather (leatherette / PVC) and a range of textiles (synthetic and non-synthetic fabrics used alone or mixed); and
- a paper-like lining material that covers the bottom or back of a unit and in some cases is used to cover the back or underside of cushions and parts of the frame behind the cushions.

A2.3 Standard item sizes

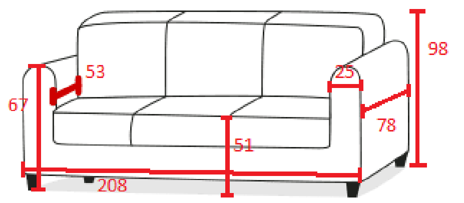
The measurements of the different item categories which have been calculated from site recorded data and online research. The summation of sizes is provided in **Error! Reference source not found.** and are used as a basis for subsequent surface area calculations for fabric covers and volume calculations for any foams and wadding. Figure A.2 provides examples of common domestic seating found on the market with their schematic diagrams and specific measurements. These can be used as a reference for the categories cited in Table A.2.

Figure A.2 Examples of common furniture categories

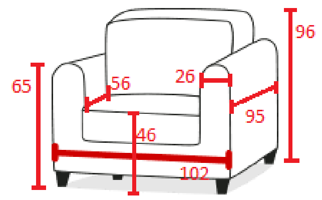
2 seater sofa



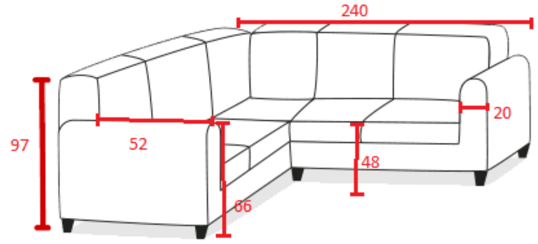
3 seater sofa



Recliner chair



5 seater corner sofa



Standard club chair

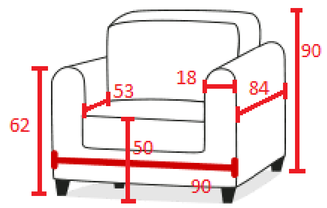


Table A.2 Range unit dimensions by domestic seating category

Item Type	Average (cm)	Minimum (cm)	Maximum (cm)
Sofa			
Width 3-seater	160	125	185
Depth	89	81	102
Height	91	66	100

Item Type	Average (cm)	Minimum (cm)	Maximum (cm)
Recliner armchair			
Overall width	95	68	102
Overall Depth	95	95	96
Overall Height	99	96	104

Item Type	Average (cm)	Minimum (cm)	Maximum (cm)		Item Type	Average (cm)	Minimum (cm)	Maximum (cm)
Seat depth	55	51	64		Seat depth	54	51	56
Seat height	45	38	55		Seat height	48	46	49
Arm width	25	20	30		Arm width	20	15	25
Armchairs Club					***Dining chair (review range)****			
Overall width	103	95	108		Back Width	41	37	44
Overall Depth	95	90	97		Back Height	53	30	66
Overall Height	97	90	101		Seat Width	45	42	48
Seat depth	53	52	54		Seat depth	58	42	54
Seat height	52	50	55					
Arm width	25	18	30					
Wingback armchairs					***Office chair***			
Overall width	74	60	82		Back Width	43	40	45
Overall Depth	90	86	96		Back Height	54	50	60
Overall Height	101	110	92		Seat Width	52	49	54
Seat depth	52	50	54		Seat depth	46	42	50
Seat height	45	43	47		***Bar stool***			
Arm width	15	10	20		Back Width	41	37	45
Tub armchair					Back Height	33	32	33
Overall width	71	68	79		Seat Width	41	37	45
Overall Depth	66	62	70		Seat depth	38	37	38
Overall Height	75	72	78		***Other***			
Seat depth	53	44	55		Overall width	89	60	115
Seat height	42	37	46		Overall Depth	68	50	98
Arm width	15				Overall Height	43	37	50
					Overall width	89	60	115

A2.4 Standard item weights

It was not possible to measure the weight of the frame as opposed to the weight of the entire unit with covers and foams in a field setting as this would have required complete and time intensive dismantling of the complete unit. On-line market research was used as the main source of information for the weights of different domestic seating types as it provided a wider set of data than the site data which was compromised in some cases by incomplete units. The site data was used to verify the weight data in addition to data from the furniture re-use network Typical item weights are presented in Table A.3.

Table A.3 Weights by item category

Item Category	Market research data			Site data		
	Mode (kg)	Minimum (kg)	Maximum (kg)	Mode (kg)	Minimum (kg)	Maximum (kg)
Sofas						
2-seater slim	45	40	50	30 (2)	30	60
2-seater padded	55	50	60	40 (3)	40	80
2-seater recliner	65	60	70	70 (2)	70	100
3-seater slim	62	60	70	-	80	80
3-seater padded	70	65	75	-	30	100
3-seater recliner	90	80	92	-	80	100
corner recliner 5 seats	128	95	150	-	60	170
Armchairs						
Armchair, club	30	20	35	30 (3)	10	70
Wingback	25	15	28	20 (4)	20	40
Tub/bucket chair	15	12	18	20 (3)	20	30
Recliner	45	40	48	50 (2)	50	50
Chairs						
Office char	15	7	18	10 (6)	10	20
Dining chair	10	5	11	10 (6)	10	40
Bar stool	10	6	15	10 (2)	10	10
Others						
Foot stool	18	10	28	20 (2)	10	20

A2.5 Component density

The size and weight of each sample collected during the sampling campaign were recorded in the WRc laboratory and this information used to calculate the densities of the covering materials. The lengths of the sides of each sample (outer upholstery, inner lining or filler such as wadding or foam) were measured together with their dry weights. Wet site samples were dried ahead of weighing. This data was then used to calculate first the volume and secondly the density of each type of domestic seating component.

Average density values for the three main upholstery cover materials are listed in Table A.4.

Table A.4 Calculated material densities

Type of material	Average density (g/cm^3)
Leather	0.92
Leatherette	0.75
Textile	0.50
Foam	3.00
Wadding	1.50
Lining foam	1.55

Example foam density data is published in a number of technical furnishing websites[5]. The most common values range from 24 to 40 kg/m^3. Specifically, in the case of domestic seat cushions, the foam density is normally circa 28 kg/m^3. A comparison of this data with the site data indicates that the average foam density is circa 36 kg/m^3. It is postulated that significant use may have compacted the foam in discarded units leading to a higher measured density.

Combining this data an average value of 30 kg/m^3 has been used for the foam density in subsequent calculations. Foam data is reported in Table A.4 which includes with average values for the cushion foam, lining foam and wadding materials.

A3 Calculation Approach

The calculation approach is identified in Figure A.1. The calculations have been approached by:

- Assign each furniture unit to a group and sub-category for which we have calculated the mode and minimum and maximum size ranges.
- Calculate the surface area of each fabric (outer fabrics (including textile, leather and leatherette) and liners which are contained within the unit taking into account where they are found within a unit.

5 https://furnitureblog.simplicitysofas.com/blog/what-is-the-difference-between-a-sofa-cushions-foam-density-and-firmness/

- Calculating the volume of foams and waddings used in the items taking into account the differences which arise between fully padded and slim line units.

Assumptions and proportion calculations are provided below.

A3.1 Unit surface area and volume calculations

A number of variables were taken into account when calculating the relative proportions of components within different units. These include:

- *Unit volume:* The inner volume of a unit 'behind' the frame is occupied by voids / air-space.
- *Fillers and foams:* The cushions that constitute the seating and backs of sofas and armchairs are filled with 100 % foam and the shape is assumed to be a cuboid. It is assumed that padding of arms and other padded areas of the frame represent a second cushion made up of lining foam, wadding and fabric lining. This allows us to take into account the different levels of padding with units, including recliners. This layer of 2 cm foam has been assumed to be present underneath the entire outer cover to soften the edges of the main frame.
- *Upholstery covers:* the total surface of each category of item is calculated based on the frame dimensions and level of padding. The outer upholstery cover is then expressed as a fraction of the total surface area of the item. The outer cover has been assumed to be 2 mm in thickness.
- *Covers of cushions:* the surface area of each cushion is calculated as a cuboid. For textile covers the surface area is 100% of the total surface area of the cushion. In the case of leather or leatherette items only 50% of the cushions are considered to be covered in the fabric.
- *Linings:* the bottom of a unit is commonly covered by a paper-like black polyester material lining. A softer lining fabric is often used also to cover the underside and back of cushions.
- *Wadding:* an intermediate layer commonly used on top of the foam layer and before a lining material and the upholstery cover. The volume has been calculated using the outer upholstery cover surface area using an assumption of thickness of 1 cm.

In calculating the total surface area of the outer upholstery cover a refinement has been introduced for leather and leatherette covers. Observations on site identified that only the part of the cushion seen by the user was covered by the primary material. Therefore, the calculation of the total surface only takes into account fifty percent of the cushions total outer surface. For slim sofas covered in textile with movable cushions most likely the entire outer surface of the cushions is covered by the same textile.

The assumptions for the percentage surface area and volumes are summarised in Table A.5.

Table A.5 Composition assumptions for furniture items

	Surface area assumptions			Volume assumptions			
Category	Outer covers	Black lining	White lining	Lining foam	Padding foam	Padded wadding	Foam filled cushion
Sofa slim textile	70%	30%	70%	70%	-	75%	100%
Sofa slim leather	60-65%	35%	60-65%	70%	-	75%	100%
Sofa padded textile	80%	20%	80%	70%	50%	75%	100%
Sofa padded leather	80%	20%	80%	70%	50%	75%	100%
Sofa recliner/corner	80%	20%	80%	70%	50%	75%	100%

A3.2 Calculated proportion of components by unit item

Based on the assumptions and calculations presented above, the calculated surface area and volume of each component in the overall unit is provided in Table A.6 and A.7.

The percentage weight of each component for different domestic seating items are presented in Table A.8 and A.9.

The values for each component that constitutes the item are presented as an average associated with a maximum, variation (+) and minimum, variation (-), value. This approach allows to take into consideration any intrinsic variability that each item may have due to differences in the size and weight. The range data was calculated using the average, minimum and maximum size values presented in Table A.2 and A.3.

Table A.6 Average armchair and chair component surface areas and volumes

Group	Category	Total surface of the item (cm^2)	Outer cover surface area (cm^2)	Foam volume (cm^3)	Wadding volume (cm^3)	Inter lining surface area (cm^2)
Armchair	Club (incl. rolled arm)	64,900	49,900	218,400	48,600	14,900
	Wingback	46,200	35,700	132,300	34,700	10,600
	Tub/Bucket	37,000	29,700	109,700	27,800	7,400
	Recliner	67,100	52,200	251,600	50,300	14,8000
Chair	Dining Chair	8,600	6,500	16,200	3,200	2,200
	Office Chair	7,000	4,700	17,700	2,400	2,400
	Bar stool	7,200	5,700	11,000	2,900	1,500

Table A.7 Average sofa component surface areas and volumes

Category	Total surface of the item (cm^2)	Outer cover surfaces (cm^2)	Foam volumes (cm^3)	Wadding volumes (cm^3)	Inter lining surfaces (cm^2)
Textile sofas					
2-seater slim	96,300	73,100	302,200	72,200	23,200
2-seater padded	106,000	83,100	535,700	79,500	22,900
3-seater slim	124,700	94,200	403,400	93,500	30,500
3-seater padded	141,000	109,700	746,300	105,800	31,300
Leather and leatherette sofas					
2-seater slim	97,000	62,000	303,200	72,800	35,000
2-seater padded	106,600	72,100	536,400	80,000	34,500
2-seater recliner	144,900	95,100	726,500	108,700	49,900
3-seater slim	124,700	79,000	403,400	93,500	45,700
3-seater padded	141,000	93,300	746,300	105,800	47,700
3-seater recliner	169,700	112,100	900,900	127,300	57,600
Corner sofa 5 seats recliner	234,000	156,600	1,351,800	175,500	77,500

A3.3 Comparison with WRAP data

The WRAP study (Benefits of Reuse Case Study: Domestic Furniture, 2011) mentioned in its final report that *"An 'average' sofa is modelled as being made of particleboard (63%), foam (PUR) (9%), woven cotton (8%), softwood (8%), low alloyed steel (8%), polyester (3%), phosphorous (used in flame retardants) (1%) and melamine (1%)."*

These findings are lower than the proportions calculated in the table above. The numbers are comparable with the slim textile sofas, but not of the other types of sofas. However, it is reasonable for the covers of sofas to account for a larger proportion especially when materials like leather are used due to its greater density than textiles.

Table A.8 Relative proportions of covers in each domestic seating item

Group	Category	Cover leather wt.%	Variation (-)	Variation (+)	Cover leatherette wt.%	Variation (-)	Variation (+)	Cover textile wt.%	Variation (-)	Variation (+)
Sofas										
2-seater	Slim	25	4.1	0.3	21	3.3	0.3	16	2.7	0.2
	Padded	22	3.9	2.9	18	3.1	2.4	14	2.6	1.8
	Recliner	22	1.8	3.1	18	1.5	2.5	12	1	1.7
3-seater	Slim	22	3.5	1.6	18	2.8	1.3	14	2.2	0.9
	Padded	25	3.5	1.6	20	2.8	1.3	16	2.2	0.9
	Recliner	20	5.7	2.5	16	4.6	2.1	11	3.1	1.4
Corner sofa (5-seater)		23	7.9	3.3	18	6.4	2.7	12	4.3	1.8
Chairs										
Armchair	Club (incl. rolled arm)	10	0.6	0.6	6	0.4	0.4	4	0.3	0.3
	Wingback	12	0.5	0.5	8	0.3	0.3	5	0.2	0.2
	Tub/Bucket	14	2.5	2.5	10	1.7	1.7	6	1	1
	Recliner	7	0.8	0.8	5	0.5	0.5	3	0.3	0.3
Chair*	Dining chair	12	1.4	1.4	10	1.2	1.2	6	0.8	0.8
	Office chair	6	2.9	2.9	5	2.4	2.4	3	1.6	1.6
Other*	Bar stool	11	4.2	4.2	9	3.4	3.4	6	2.3	2.3

Table A.9 Relative proportions of filling components in each domestic seating item

Group	Category	Wadding wt.%	range	Foam wt.%	range	Lining wt.%
Sofas						
2-seater	Slim	2	+/-0.6%	11	+/- 3%	0.6
	Padded	2	+/-0.5%	19	+/- 4%	0.6
	Recliner	1	+/-0.3%	15	+/- 3%	0.7
3-seater	Slim	2	+/-0.5%	17	+/- 2%	0.7
	Padded	2	+/-0.5%	35	+/- 5%	0.9
	Recliner	2	+/-0.9%	35	+/- 2%	0.8
Corner sofa (5-seater)		1		42	+/- 3%	1
Chairs						
Armchair	Club (incl. rolled arm)	2	+/-0.2%	10	+/-2%	0.2
	Wingback	2	+/-0.1%	13	+/-1%	0.3
	Tub/Bucket	3	+/-0.5%	12	+/-1%	0.6
	Recliner	1	+/-0.1%	9	+/-3%	0.5
Chair*	Dining chair	1		4		0.4
	Office chair	0.2		3		0.3
Other*	Bar stool	0.3		2		0.2

Appendix B Item Label Information

During site sampling, all units were assessed to determine whether they had any labels present including brand, country of manufacture and whether or not flammability labels were present. Only 20% of the items taken from waste sites (excluding the re-use site) had a fire label attached. The fire labels were predominantly those which stated the items conformed to the Furniture and Furnishings (Fire Safety) Regulations 1988/1989, 1993 or 2010 alongside a label which stated whether the filling was match or cigarette resistant. For the majority of the items, no other labels or information were either present or readable. This may be partly due to them being removed by the owners, the print had worn off during use and cleaning, or the item was damaged or not completely present during sampling as it was often the case that at the waste sites only part of the item was present or it has been damaged during compaction or transport. For those items that did include additional labels, the information is displayed in Table B.1 below. The samples highlighted underwent the Tier 3 chemical testing.

There does not seem to be a correlation between having a fire label and bromine being present. There are plenty of units with labels and no bromine. There are also examples in this table (but obviously in the rest of the dataset) where bromine is present without a fire label, but this might be because it has been removed.

Table B.1 Item labelling information (where available and applicable)

Item	Type	XRF Bromine >0.1% wt.	Fire label	Manufacturer	Brand/Model	Origin	Age
CC1	Sofa	Foam, lining	Yes				
CC2	Sofa	Cover, lining	No		F8753M		2013
CC3	Sofa	None	Yes	Furniture Village	Trilogy		
CC4	Armchair	Cover, foam	Yes				
CC5	Sofa	Cover, wadding, lining	Yes				
CC7	Armchair	Cover, foam	Yes				2014
CC8	Armchair	Cover, foam, lining	Yes	M & S	Abbey		2001
CC10	Sofa	Cover, wadding	No	Carpenter Ltd Cotus Branch	Camden Lounger ST RX36100		2011
CC11	Sofa	Cover, foam	Yes	Next			
CC21	Armchair	Lining	Yes				
WF1	Dining chair	None	Yes				
WF5	Dining chair	Cover	Yes				
WF7	Office chair	None	Yes	IKEA	Tokkel	Made in China	
WF8	Other	None	Yes				
WF10	Other	Lining	Yes				

Item	Type	XRF Bromine >0.1% wt.	Fire label	Manufacturer	Brand/Model	Origin	Age
WF12	Other	None	Yes				
WF13	Armchair	None	Yes	IKEA	001.008.77/18871	Made in Poland	
WF15	Office chair	None	Yes				
WF17	Office chair	Lining	Yes	Julian Bowen	Malmo Recliner & Footstool - Brown		
WF18	Armchair	Lining	Yes	Land of Leather			01 May 2008
WF19	Sofa	None	No				06 June 2006
WF20	Sofa	None	Yes	Land of Leather			
WF23	Armchair	None	No	Parker knoll			
WF24	Armchair	Cover	Yes	jc & mp smith ltd furniture	#297525		
WF25	Sofa	None	Yes			Made in Poland (?)	
WF26	Armchair	None	Yes		# 1004542		
KM1	Armchair	Cover, lining	Yes				
KM4	Sofa	Lining, foam	Yes				
KM5	Sofa	Lining	No				2007
KM7	Sofa	None	Yes				2003
KM10	Sofa	Cover	Yes				2009
KM11	Other	Cover, lining	Yes				2016
KM12	Armchair	Lining	Yes				2005
KM18	Armchair	Lining	Yes	IKEA			1999
KM20	Sofa	Foam	Yes				2006
KM25	Sofa	Cover	Yes				2004
KM29	Armchair	None	Yes				
KM32	Office chair	None	Yes				
KM33	Office chair	None	Yes				
KM34	Sofa	Cover	Yes				
KM39	Dining chair	None	Yes				
KM40	Sofa	Cover, foam	Yes				
KM45	Armchair	Cover, foam	Yes				
LC1	Sofa	Cover, foam	Yes				2017
LC2	Sofa	None	Yes				2010
LC3	Sofa	Cover	Yes				2015
LC4	Sofa	None	No				2003
LC6	Sofa	Cover, lining	Yes				
LC15	Sofa	Cover	Yes				2014

Item	Type	XRF Bromine >0.1% wt.	Fire label	Manufacturer	Brand/Model	Origin	Age
LC18	Sofa	Cover	Yes				
HH38	Sofa	None	Yes	Next - Home			
SP3	Sofa	Cover	Yes		DFS		
SP5	Sofa	Cover	Yes		DFS		
SP6	Sofa	None	Yes		Comfortex		
SP7	Sofa	Cover, foam	Yes				
SP8	Sofa	Cover	Yes		M&S		
SP10	Office chair	None	Yes		IKEA		
SP11	Armchair	None	Yes		John Lewis		
SP12	Armchair	Cover	Yes		G. Plan		
SP26	Sofa	Cover, foam	Yes		M&S		
SP41	Armchair	Cover	Yes		Quartz Contracts		
SP43	Sofa	None	Yes		Multiyork		

Appendix C Tier 1 - XRF Screening

C1 XRF Scanning Data

For the first tier of the assessment, chemical screening using a handheld XRF analyser was primarily undertaken to determine the bromine concentration in the sampled components, as bromine is the key indicator of BFRs. XRF analysis cannot identify specific compounds that are present, but allows the selection of samples with significant levels of bromine present to be selected for more complex analytical testing. As well as the bromine concentration the analyser was able to determine the concentration of other parameters such as chlorine, and antimony The concentrations of the other elements can provide some insight into either the type of material (e.g. high chlorine can be linked to PVC) or identify if specific synergists or additives have been used which can be linked to the use of a wider range of flame retardants.

In total 985 XRF scans were undertaken on the furnishing components taken from the sampled domestic seating units. A traffic light system has been applied to the XRF data based on the bromine concentration. The thresholds used in the traffic light assessment are identified in Table C.1. The XRF data set is provided in Table C.2.

Table C.1 Key for XRF data table

Trace	Transition	Functional
Br < 1,000	1,000 < Br < 10,000	Br ≥ 10,000
Sb < 1,000	1,000 < Sb < 10,000	Sb ≥ 10,000

Table C.2 Bromine, antimony and chlorine data for all scanned components

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	CC1-A	Cover (leather)	39.2	0.00	0.00
Sofa	CC1-B	Wadding	10.2	176	0.00
Sofa	CC1-C	Foam	4,499	0.00	0.00
Sofa	CC1-D	Lining	2,783	162	0.00
Sofa	CC1-E	Misc.	149	0.00	0.00
Sofa	CC1-F	Lining	28.8	55.1	0.00
Sofa	CC1-G	Lining	38.5	71.6	0.00
Sofa	CC2-A	Lining	6,709	0.00	0.00
Sofa	CC2-B	Lining	8,406	44.5	0.00
Sofa	CC2-C	Foam	633	151	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	CC2-D	Foam	128	0.00	0.00
Sofa	CC2-E	Lining	1,124	354	0.00
Sofa	CC2-F	Lining	30.1	0.00	0.00
Sofa	CC2-G	Cover (leatherette)	6,602	52.1	0.00
Sofa	CC2-H	Cover (leatherette)	7,736	65.6	0.00
Sofa	CC3-A	Lining	27,997	5,055	0.00
Sofa	CC3-B	Lining	227	120	0.00
Sofa	CC3-C	Foam	626	82.6	0.00
Sofa	CC3-D	Lining	15.0	0.00	0.00
Sofa	CC3-E	Lining	45.9	0.00	0.00
Armchair	CC4-A	Lining	31.9	75.0	0.00
Armchair	CC4-B	Cover (textile)	52,882	11,621	0.00
Armchair	CC4-C	Foam	98.0	0.00	0.00
Armchair	CC4-D	Foam	1,354	184	0.00
Armchair	CC4-E	Lining	23.3	0.00	0.00
Armchair	CC4-F	Wadding	93.9	58.4	0.00
Armchair	CC4-G	Lining	30.0	0.00	0.00
Sofa	CC5-A	Cover (leatherette)	31,659	2,790	0.00
Sofa	CC5-B	Foam	208	0.00	0.00
Sofa	CC5-C(A)	Wadding	6,141	754	0.00
Sofa	CC5-C(B)	Wadding	2,138	193	0.00
Sofa	CC5-D	Lining	6,292	378	0.00
Sofa	CC5-E(A)	Lining	5,930	326	0.00
Sofa	CC5-E(B)	Lining	44,634	4,134	0.00
Sofa	CC5-F	Lining	42.7	69.3	0.00
Sofa	CC5-G	Misc.	139	36.7	0.00
Dining chair	CC6-A	Cover (textile)	61,475	22,030	0.00
Dining chair	CC6-B	Lining	143	103	0.00
Dining chair	CC6-C	Wadding	50.8	102	0.00
Dining chair	CC6-D	Foam	89.9	0.00	0.00
Dining chair	CC6-E	Misc.	15.4	0.00	0.00
Armchair	CC7-A	Lining	440	115	0.00
Armchair	CC7-B	Wadding	450	197	0.00
Armchair	CC7-C	Cover (textile)	61,741	9,288	0.00
Armchair	CC7-D	Lining	265	55.7	0.00
Armchair	CC7-E	Cover (textile)	32,332	3,973	0.00
Armchair	CC7-F	Misc.	900	70.0	0.00
Armchair	CC7-G	Foam	1,560	118	0.00
Armchair	CC8-A	Cover (textile)	62,751	31,029	0.00
Armchair	CC8-B	Lining	3,056	412	0.00
Armchair	CC8-C	Wadding	547	236	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Armchair	CC8-D	Lining	383	194	0.00
Armchair	CC8-E	Wadding	542	207	0.00
Armchair	CC8-F	Lining	1,199	200	0.00
Armchair	CC8-G	Lining	2,520	582	0.00
Armchair	CC8-H	Foam	5,316	683	0.00
Armchair	CC8-I	Lining	115	0.00	0.00
Armchair	CC8-J	Misc.	104	203	0.00
Armchair	CC8-K	Misc.	1,040	211	0.00
Armchair	CC8-L	Lining	149	65.6	0.00
Sofa	CC9-A	Lining	23.3	0.00	0.00
Sofa	CC9-B	Wadding	26.0	33.2	0.00
Sofa	CC9-C	Cover (textile)	40,403	8,478	0.00
Sofa	CC9-D	Cover (textile)	61,196	7,751	0.00
Sofa	CC9-E	Foam	17.7	0.00	0.00
Sofa	CC9-F	Foam	11.6	0.00	0.00
Sofa	CC10-A	Cover (textile)	11,327	4,011	0.00
Sofa	CC10-B	Wadding	1,381	363	0.00
Sofa	CC10-C	Foam	0.00	0.00	0.00
Sofa	CC11-A	Lining	212	67.1	0.00
Sofa	CC11-B	Cover (textile)	40,580	3,825	0.00
Sofa	CC11-C	Wadding	49.2	141	0.00
Sofa	CC11-D	Foam	3,713	160	0.00
Sofa	CC13-A	Cover (leather)	44.3	0.00	0.00
Sofa	CC13-B	Lining	33.4	0.00	0.00
Sofa	CC13-C	Foam	187	0.00	0.00
Sofa	CC13-D	Lining	138	76.6	0.00
Sofa	CC13-E	Misc.	22.7	0.00	0.00
Sofa	CC13-F	Misc.	21.4	34.0	0.00
Sofa	CC13-G	Lining	4,154	418	0.00
Sofa	CC13-H	Foam	3,523	0.00	0.00
Sofa	CC13-I	Lining	3,254	701	0.00
Sofa	CC13-J	Wadding	16.0	149	0.00
Sofa	CC13-K	Misc.	69.9	0.00	0.00
Sofa	CC15-A	Foam	0.00	0.00	0.00
Sofa	CC15-B	Wadding	8.07	66.9	0.00
Sofa	CC15-C	Lining	6,789	2,309	0.00
Sofa	CC15-D	Cover (textile)	33,923	11,635	0.00
Sofa	CC15-E	Cover (textile)	146	0.00	0.00
Sofa	CC17-A	Cover (textile)	66,968	12,947	0.00
Sofa	CC17-B	Foam	8,481	158	0.00
Sofa	CC19-A	Wadding	733	85.8	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	CC19-B	Foam	232	0.00	0.00
Sofa	CC19-C	Cover (textile)	24,103	2,119	0.00
Sofa	CC19-D	Cover (textile)	12,485	756	0.00
Sofa	CC19-E	Lining	178	0.00	0.00
Armchair	CC21-A	Foam	103	0.00	0.00
Armchair	CC21-B	Lining	7,187	1,519	0.00
Armchair	CC21-C	Misc.	84.4	0.00	0.00
Armchair	CC21-D	Cover (leatherette)	9.66	63.5	0.00
Armchair	CC21-E	Wadding	57.4	64.7	0.00
Armchair	CC21-F	Lining	9,648	1,803	0.00
Armchair	CC23-A	Lining	6,618	493	0.00
Armchair	CC23-B	Cover (textile)	36,263	1,121	0.00
Armchair	CC23-C	Cover (textile)	46,327	1,718	0.00
Armchair	CC23-D	Lining	8,801	361	0.00
Armchair	CC23-E	Foam	41.1	0.00	0.00
Armchair	CC23-F	Misc.	46.2	0.00	0.00
Sofa	CC25-A	Foam	13.4	114	0.00
Sofa	CC25-B	Cover (textile)	44,989	2,232	0.00
Sofa	CC25-C	Lining	549	32.0	0.00
Sofa	CC27-A	Misc.	4,196	1,683	0.00
Sofa	CC27-B	Cover (textile)	33,109	16,142	0.00
Sofa	CC27-C	Lining	1,092	41.8	0.00
Sofa	CC27-D	Foam	11.5	0.00	0.00
Dining chair	WF1-A	Cover (leatherette)	67.6	1,123	360,000
Dining chair	WF1-B	Foam	0.00	0.00	0.00
Dining chair	WF1-C	Lining	10.4	0.00	0.00
Dining chair	WF2-A	Cover (leatherette)	23,434	77.8	0.00
Dining chair	WF2-B	Wadding	1,559	116	0.00
Dining chair	WF2-C	Foam	100	0.00	0.00
Dining chair	WF2-D	Lining	8,182	1,623	0.00
Dining chair	WF3-A	Cover (leather)	16.7	0.00	0.00
Dining chair	WF3-B	Wadding	0.00	151	0.00
Dining chair	WF3-C	Cover (textile)	8.47	0.00	0.00
Dining chair	WF3-D	Wadding	0.00	0.00	0.00
Dining chair	WF4-A	Cover (leather)	29.2	0.00	0.00
Dining chair	WF4-B	Foam	16.2	0.00	88,268
Dining chair	WF4-C	Lining	527	70.6	0.00
Dining chair	WF5-A	Cover (textile)	30,602	26,225	0.00
Dining chair	WF5-B	Foam	175	86.4	0.00
Office chair	WF6-A	Cover (textile)	528	35.0	0.00
Office chair	WF6-B	Foam	17,698	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg-1		
			Br	Sb	Cl
Office chair	WF7-A	Cover (leatherette)	6.38	91.3	0.00
Office chair	WF7-B	Lining	16.5	0.00	0.00
Office chair	WF7-C	Wadding	12.0	0.00	0.00
Office chair	WF7-D	Wadding	7.70	104	0.00
Other	WF8-A	Cover (textile)	6.43	0.00	0.00
Other	WF8-B	Wadding	14.6	0.00	0.00
Other	WF8-C	Cover (textile)	16.3	69.7	0.00
Other	WF8-D	Foam	16.2	0.00	0.00
Other	WF8-E	Lining	13.8	0.00	0.00
Other	WF8-F	Wadding	199	121	0.00
Other	WF9-A	Cover (textile)	35,526	8,252	0.00
Other	WF9-B	Foam	1,315	115	50,985
Other	WF9-C	Lining	20.8	0.00	0.00
Other	WF10-A(A)	Lining	415	0.00	0.00
Other	WF10-A(B)	Cover (leatherette)	0.00	360	360,000
Other	WF10-B	Lining	1,452	0.00	0.00
Other	WF10-C	Wadding	11.0	0.00	0.00
Other	WF11-A	Cover (textile)	23.6	0.00	0.00
Other	WF11-B	Cover (textile)	8.51	0.00	0.00
Other	WF11-C	Foam	13.7	0.00	0.00
Other	WF12-A	Cover (textile)	0.00	59.5	0.00
Other	WF12-B	Lining	25.0	65.6	0.00
Other	WF12-C	Cover (textile)	6.02	0.00	0.00
Armchair	WF13-A	Cover (textile)	17.8	0.00	0.00
Armchair	WF13-B	Wadding	0.00	140	0.00
Armchair	WF13-C	Foam	18.7	0.00	0.00
Armchair	WF13-D	Lining	26.7	0.00	0.00
Armchair	WF13-E	Cover (textile)	3.65	0.00	0.00
Armchair	WF14-A	Cover (textile)	19.7	0.00	0.00
Armchair	WF14-B	Foam	6.03	0.00	0.00
Armchair	WF14-C	Lining	13.6	34.8	0.00
Office chair	WF15-A	Cover (leather)	35.7	0.00	0.00
Office chair	WF15-B	Foam	35.1	0.00	0.00
Office chair	WF15-C	Lining	20.6	0.00	0.00
Sofa	WF16-A	Cover (leatherette)	68,766	16,562	0.00
Sofa	WF16-B	Cover (textile)	69,901	15,727	0.00
Sofa	WF16-C	Foam	5,681	586	0.00
Sofa	WF16-D	Lining	291	53.8	0.00
Sofa	WF16-E	Cover (leatherette)	38,643	5,190	0.00
Sofa	WF16-F	Wadding	842	228	0.00
Sofa	WF16-G	Foam	116	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	WF16-H	Lining	29.3	58.8	0.00
Office chair	WF17-A	Cover (leatherette)	27.1	2,910	360,000
Office chair	WF17-B	Wadding	8.93	111	0.00
Office chair	WF17-C	Foam	47.0	0.00	0.00
Office chair	WF17-D	Lining	2,792	451	0.00
Office chair	WF17-E	Lining	235	76.3	0.00
Office chair	WF17-F	Foam	226	0.00	0.00
Office chair	WF17-G	Lining	2,220	834	0.00
Armchair	WF18-A(A)	Cover (leather)	111	0.00	0.00
Armchair	WF18-A(B)	Cover (leather)	15.4	0.00	0.00
Armchair	WF18-B	Lining	115	60.2	0.00
Armchair	WF18-D	Foam	2,616	0.00	0.00
Armchair	WF18-E	Lining	1,957	122	0.00
Sofa	WF19-A	Cover (leather)	0.00	39.9	0.00
Sofa	WF19-B	Foam	6.19	0.00	0.00
Sofa	WF19-C	Lining	141	45.5	0.00
Sofa	WF20-A	Cover (leather)	53.5	0.00	0.00
Sofa	WF21-A	Cover (leatherette)	0.00	250	360,000
Sofa	WF21-B	Foam	0.00	0.00	0.00
Sofa	WF21-C	Foam	62.3	0.00	0.00
Sofa	WF21-D	Lining	2,332	367	0.00
Sofa	WF22-A	Cover (leather)	28.2	0.00	0.00
Sofa	WF22-B	Foam	10.7	167	0.00
Sofa	WF22-C	Foam	0.00	0.00	0.00
Sofa	WF22-D	Cover (leather)	12.7	0.00	0.00
Sofa	WF22-E	Foam	9.17	0.00	0.00
Armchair	WF23-A	Cover (textile)	11.1	0.00	0.00
Armchair	WF23-B	Wadding	14.3	0.00	0.00
Armchair	WF24-A	Cover (textile)	89,449	13,166	0.00
Armchair	WF24-B	Foam	32.7	0.00	0.00
Armchair	WF24-C	Lining	54.0	0.00	0.00
Sofa	WF25-A	Cover (textile)	20.7	0.00	0.00
Sofa	WF25-B	Foam	12.8	0.00	0.00
Sofa	WF25-C	Lining	15.1	92.5	0.00
Armchair	WF26-A	Cover (leatherette)	20.2	2,709	360,000
Armchair	WF26-B	Wadding	16.3	74.4	0.00
Armchair	WF26-C	Foam	7.30	0.00	0.00
Armchair	WF26-D	Lining	8.78	0.00	0.00
Armchair	WF26-E	Lining	26.2	0.00	0.00
Sofa	WF27-A	Cover (textile)	63.9	118	0.00
Sofa	WF27-B	Wadding	365	200	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	WF27-C	Foam	0.00	0.00	0.00
Sofa	WF27-D	Lining	68.0	35.8	0.00
Sofa	WF27-E	Lining	50.6	64.8	0.00
Sofa	WF28-A	Cover (leatherette)	8.94	10,983	360,000
Armchair	KM1-A	Lining	1,035	101	0.00
Armchair	KM1-B	Wadding	0.00	85.4	0.00
Armchair	KM1-C	Wadding	68.0	96.2	0.00
Armchair	KM1-D	Lining	197	0.00	0.00
Armchair	KM1-E	Lining	142	0.00	0.00
Armchair	KM1-F	Cover (textile)	12,345	2,719	0.00
Armchair	KM2-A	Cover (leatherette)	0.00	6,581	360,000
Armchair	KM2-B	Lining	15.2	0.00	0.00
Armchair	KM2-C	Foam	0.00	0.00	0.00
Armchair	KM2-D	Lining	0.00	0.00	0.00
Armchair	KM2-E	Lining	11.1	0.00	0.00
Armchair	KM2-F	Misc.	0.00	0.00	0.00
Sofa	KM3-A	Wadding	0.00	118	0.00
Sofa	KM3-B	Lining	0.00	0.00	0.00
Sofa	KM3-C	Foam	0.00	0.00	0.00
Sofa	KM3-D	Cover (leather)	41.1	0.00	0.00
Sofa	KM3-E	Foam	0.00	0.00	0.00
Sofa	KM4-A	Lining	4,817	1,634	0.00
Sofa	KM4-B	Wadding	149	126	0.00
Sofa	KM4-C	Cover (leatherette)	230	2,499	360,000
Sofa	KM4-D	Lining	4,534	808	0.00
Sofa	KM4-E	Foam	1,193	0.00	0.00
Sofa	KM4-F	Lining	9.84	90.0	0.00
Sofa	KM4-G	Foam	0.00	0.00	0.00
Sofa	KM4-H	Foam	149	0.00	0.00
Sofa	KM5-A	Cover (leather)	0.00	0.00	0.00
Sofa	KM5-B	Cover (leatherette)	415	94.7	0.00
Sofa	KM5-C	Cover (leather)	11.3	0.00	0.00
Sofa	KM5-D	Wadding	7.22	158	0.00
Sofa	KM5-E	Lining	17.0	56.1	0.00
Sofa	KM5-F	Lining	3,870	1,263	0.00
Sofa	KM5-G	Foam	8.36	0.00	0.00
Sofa	KM5-H	Foam	6.57	43.4	0.00
Sofa	KM6-A	Cover (leather)	12.4	0.00	0.00
Sofa	KM6-B	Wadding	0.00	103	0.00
Sofa	KM6-C	Lining	11.3	0.00	0.00
Sofa	KM6-D	Foam	9.42	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	KM7-A	Cover (leather)	18.7	0.00	0.00
Sofa	KM7-B	Wadding	0.00	144	0.00
Sofa	KM7-C	Cover (leather)	8.36	0.00	0.00
Sofa	KM7-D	Lining	0.00	0.00	0.00
Sofa	KM7-E	Wadding	0.00	113	0.00
Sofa	KM7-F	Foam	0.00	0.00	0.00
Sofa	KM7-G	Foam	5.65	0.00	0.00
Dining chair	KM8-A	Lining	9.01	0.00	0.00
Dining chair	KM8-B	Lining	6.57	0.00	0.00
Dining chair	KM8-C	Wadding	0.00	172	0.00
Dining chair	KM8-D	Cover (textile)	0.00	0.00	0.00
Armchair	KM9-A	Cover (leather)	22.6	0.00	0.00
Armchair	KM9-B	Wadding	0.00	133	0.00
Armchair	KM9-C	Lining	0.00	0.00	0.00
Sofa	KM10-A	Cover (leatherette)	14,162	3,252	0.00
Sofa	KM10-B	Foam	52.5	0.00	0.00
Sofa	KM10-C	Lining	19.4	85.1	0.00
Other	KM11-A	Foam	39.0	0.00	0.00
Other	KM11-B	Lining	1,033	96.9	0.00
Other	KM11-C	Lining	136	33.0	0.00
Other	KM11-D	Cover (textile)	96,767	8,608	0.00
Armchair	KM12-A	Cover (leather)	7.20	0.00	0.00
Armchair	KM12-B	Cover (leather)	42.1	0.00	0.00
Armchair	KM12-C	Foam	13.3	0.00	0.00
Armchair	KM12-D	Foam	6.58	0.00	0.00
Armchair	KM12-E	Lining	4,505	2,141	0.00
Armchair	KM12-F	Wadding	22.9	139	0.00
Sofa	KM13-A	Cover (textile)	13,482	1,955	0.00
Sofa	KM13-B	Lining	9.99	50.2	0.00
Sofa	KM13-C	Wadding	0.00	152	0.00
Sofa	KM14-A	Cover (textile)	78,799	7,135	0.00
Sofa	KM14-B	Wadding	54.9	141	0.00
Armchair	KM15-A	Cover (leather)	34.0	0.00	0.00
Armchair	KM15-B	Lining	14.3	0.00	0.00
Armchair	KM15-C	Foam	32.9	0.00	0.00
Armchair	KM15-D	Lining	9.67	122	0.00
Sofa	KM16-A	Cover (textile)	96,401	10,656	0.00
Sofa	KM16-B	Foam	0.00	0.00	0.00
Sofa	KM16-C	Wadding	855	248	0.00
Sofa	KM16-D	Foam	0.00	0.00	0.00
Sofa	KM17-A	Cover (textile)	63,138	32,067	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	KM17-B	Foam	4,749	0.00	0.00
Armchair	KM18-A	Cover (textile)	2.27	0.00	0.00
Armchair	KM18-B	Wadding	0.00	173	0.00
Armchair	KM18-C	Foam	12.5	0.00	0.00
Armchair	KM18-D	Lining	2,430	0.00	0.00
Sofa	KM19-A	Cover (textile)	0.00	95.4	0.00
Sofa	KM19-B	Wadding	0.00	155	0.00
Sofa	KM19-C	Wadding	0.00	149	0.00
Sofa	KM19-D	Foam	6.91	0.00	0.00
Sofa	KM20-A	Cover (textile)	186	0.00	0.00
Sofa	KM20-B	Lining	96.0	100	0.00
Sofa	KM20-C	Foam	14,675	0.00	0.00
Sofa	KM21-A	Cover (textile)	10.5	47.1	0.00
Sofa	KM21-B	Lining	0.00	47.6	0.00
Sofa	KM21-C	Wadding	0.00	169	0.00
Armchair	KM22-A	Cover (leatherette)	114,663	11,043	0.00
Armchair	KM22-B	Cover (textile)	66,593	6,134	0.00
Armchair	KM22-C	Foam	0.00	0.00	360,000
Armchair	KM22-D	Wadding	280	152	0.00
Armchair	KM22-E	Lining	38.3	39.7	0.00
Sofa	KM23-A	Cover (textile)	71,214	9,092	0.00
Sofa	KM23-B	Foam	0.00	0.00	0.00
Sofa	KM23-C	Lining	19.7	121	0.00
Sofa	KM23-D	Lining	4.10	0.00	0.00
Sofa	KM23-E	Lining	0.00	145	0.00
Sofa	KM23-F	Lining	28.4	0.00	0.00
Sofa	KM23-G	Wadding	0.00	74.3	0.00
Sofa	KM24-A	Cover (leatherette)	18.2	1,830	360,000
Sofa	KM24-B	Foam	24.3	0.00	0.00
Sofa	KM24-C	Wadding	1,965	129	0.00
Sofa	KM25-A	Lining	0.00	0.00	0.00
Sofa	KM25-B	Lining	21.9	0.00	0.00
Sofa	KM25-C	Lining	391	76.0	0.00
Sofa	KM25-D	Foam	593	57.1	0.00
Sofa	KM25-E	Cover (textile)	82,039	33,282	0.00
Armchair	KM26-A	Cover (leatherette)	159	68.1	0.00
Armchair	KM26-B	Lining	17.4	117	0.00
Armchair	KM26-C	Lining	10.6	0.00	0.00
Armchair	KM26-D	Foam	16,664	0.00	0.00
Armchair	KM27-A	Cover (textile)	79,769	32,807	0.00
Armchair	KM27-B	Lining	106	144	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Armchair	KM27-C	Wadding	60.7	176	0.00
Armchair	KM27-D	Foam	1,765	226	0.00
Armchair	KM27-E	Foam	97.8	0.00	0.00
Armchair	KM28-A	Cover (textile)	22.2	0.00	0.00
Armchair	KM28-B	Wadding	0.00	176	0.00
Armchair	KM28-C	Lining	4.76	0.00	0.00
Armchair	KM28-D	Wadding	133	66.5	0.00
Armchair	KM28-E	Wadding	6.87	0.00	0.00
Armchair	KM29-A	Foam	12.1	0.00	0.00
Armchair	KM29-B	Wadding	0.00	184	0.00
Armchair	KM29-C	Cover (leather)	55.0	0.00	0.00
Armchair	KM29-D	Lining	199	154	0.00
Armchair	KM29-E	Lining	45.7	0.00	0.00
Armchair	KM29-F	Foam	0.00	0.00	0.00
Armchair	KM29-G	Foam	0.00	0.00	0.00
Dining chair	KM30-A	Cover (textile)	686	147	0.00
Dining chair	KM30-B	Cover (textile)	2,527	98.7	0.00
Dining chair	KM30-C	Foam	11.6	0.00	0.00
Dining chair	KM30-D	Foam	17.5	0.00	0.00
Office chair	KM31-A	Cover (textile)	9.83	0.00	0.00
Office chair	KM31-B	Foam	15.1	0.00	0.00
Office chair	KM31-C	Foam	48.3	0.00	0.00
Office chair	KM32-A	Cover (textile)	38.7	0.00	0.00
Office chair	KM32-B	Foam	17.2	0.00	0.00
Office chair	KM33-A	Cover (textile)	132	92.3	0.00
Office chair	KM33-B	Foam	26.1	0.00	0.00
Office chair	KM33-C	Foam	10.8	0.00	0.00
Sofa	KM34-A	Cover (textile)	77,056	29,489	0.00
Sofa	KM34-B	Foam	409	68.4	0.00
Sofa	KM35-A	Cover (textile)	469	104	0.00
Sofa	KM35-B	Foam	0.00	0.00	0.00
Sofa	KM35-C	Lining	14.3	0.00	0.00
Sofa	KM35-D	Wadding	40.8	165	0.00
Sofa	KM35-E	Wadding	22.4	130	0.00
Dining chair	KM36-A	Cover (leatherette)	7.52	44.7	360,000
Dining chair	KM36-B	Foam	13.0	0.00	0.00
Dining chair	KM36-C	Lining	0.00	0.00	0.00
Sofa	KM37-A	Cover (leather)	18.8	0.00	0.00
Sofa	KM37-B	Foam	12,047	0.00	0.00
Other	KM38-A	Cover (textile)	672	100	0.00
Other	KM38-B	Cover (textile)	48,346	6,473	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Other	KM38-C	Foam	2,050	163	0.00
Other	KM38-D	Lining	10.4	0.00	0.00
Dining chair	KM39-A	Cover (leatherette)	0.00	956	360,000
Dining chair	KM39-B	Foam	7.80	0.00	0.00
Dining chair	KM39-C	Lining	161	60.3	0.00
Dining chair	KM39-D	Lining	327	62.3	0.00
Sofa	KM40-A	Cover (textile)	25,037	2,136	0.00
Sofa	KM40-B	Lining	789	55.3	0.00
Sofa	KM40-C	Foam	16,102	1,325	0.00
Sofa	KM40-D	Wadding	190	173	0.00
Sofa	KM41-A	Lining	0.00	0.00	0.00
Sofa	KM41-B	Foam	4.23	0.00	0.00
Sofa	KM41-C	Cover (leather)	51.4	0.00	0.00
Dining chair	KM42-A	Cover (leatherette)	0.00	1,841	360,000
Dining chair	KM42-B	Cover (leatherette)	42.8	2,953	360,000
Dining chair	KM42-C	Cover (leatherette)	39.0	2,239	360,000
Dining chair	KM42-D	Foam	0.00	0.00	0.00
Dining chair	KM42-E	Foam	0.00	0.00	0.00
Office chair	KM43-A	Foam	25.1	0.00	0.00
Office chair	KM43-B	Cover (textile)	13.2	0.00	0.00
Sofa	KM44-A	Cover (textile)	0.00	0.00	0.00
Sofa	KM44-B	Foam	5.14	0.00	0.00
Armchair	KM45-A	Cover (textile)	80,179	22,426	0.00
Armchair	KM45-B	Lining	139	494	0.00
Armchair	KM45-C	Foam	1,933	81.1	360,000
Armchair	KM45-D	Wadding	88.9	210	0.00
Office chair	KM46-A	Cover (textile)	678	140	0.00
Office chair	KM46-B	Foam	91.5	0.00	0.00
Armchair	KM47-A	Foam	22.0	0.00	0.00
Armchair	KM47-B	Cover (leather)	0.00	0.00	0.00
Armchair	KM47-C	Lining	7.42	0.00	0.00
Sofa	LC1-A	Cover (textile)	23,222	102	0.00
Sofa	LC1-B	Foam	1,069	0.00	0.00
Sofa	LC1-C	Lining	617	0.00	0.00
Sofa	LC2-A	Cover (textile)	402	0.00	0.00
Sofa	LC2-B	Lining	5.99	0.00	0.00
Sofa	LC2-C	Foam	0.00	0.00	0.00
Sofa	LC3-A	Cover (textile)	40,054	5,856	0.00
Sofa	LC3-B	Foam	238	0.00	0.00
Sofa	LC3-C	Cover (textile)	37,808	5,233	0.00
Sofa	LC3-D	Lining	191	100	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	LC3-E	Lining	85.4	33.7	0.00
Sofa	LC4-A	Lining	6.70	169	0.00
Sofa	LC4-B	Cover (leather)	12.8	0.00	0.00
Sofa	LC4-C	Foam	0.00	0.00	0.00
Dining chair	LC5-A	Cover (leatherette)	23.3	11,809	0.00
Dining chair	LC5-B	Wadding	45.3	172	0.00
Dining chair	LC5-C	Foam	386	0.00	0.00
Sofa	LC6-A	Cover (textile)	84,617	34,769	0.00
Sofa	LC6-B	Lining	2,088	392	0.00
Sofa	LC6-C	Wadding	493	279	0.00
Office chair	LC7-A	Cover (leatherette)	1,614	7,971	217,318
Office chair	LC7-B	Cover (leatherette)	1,028	21.3	360,000
Office chair	LC7-C	Foam	8.15	0.00	0.00
Office chair	LC7-D	Lining	9,297	0.00	0.00
Sofa	LC8-A	Foam	19.6	0.00	0.00
Sofa	LC8-B	Cover (leather)	22.5	0.00	0.00
Sofa	LC8-C	Lining	677	142	0.00
Sofa	LC8-D	Wadding	10.1	198	0.00
Sofa	LC8-E	Misc.	8.95	0.00	0.00
Office chair	LC9-A	Cover (leatherette)	38.8	6,039	360,000
Office chair	LC9-B	Foam	41.1	0.00	0.00
Office chair	LC10-A	Lining	4,890	244	0.00
Office chair	LC10-B	Lining	558	86.5	0.00
Office chair	LC10-C	Foam	22.4	0.00	0.00
Sofa	LC12-A	Cover (leather)	20.9	0.00	0.00
Sofa	LC12-B	Wadding	6.22	194	0.00
Sofa	LC12-C	Foam	5.40	0.00	360,000
Sofa	LC13-A	Cover (textile)	15,876	8,615	0.00
Sofa	LC13-B	Lining	1,426	322	0.00
Sofa	LC13-C	Wadding	18.1	107	0.00
Sofa	LC14-A	Cover (leather)	48.6	0.00	0.00
Sofa	LC14-B	Lining	7.94	103	0.00
Sofa	LC14-C	Foam	0.00	0.00	0.00
Sofa	LC14-D	Wadding	44.6	112	0.00
Sofa	LC15-A	Cover (textile)	86,968	7,583	0.00
Sofa	LC15-B	Cover (textile)	105,372	8,695	0.00
Sofa	LC15-C	Lining	45.6	0.00	0.00
Sofa	LC15-D	Wadding	27.4	148	0.00
Sofa	LC15-E	Foam	11.5	0.00	0.00
Sofa	LC16-A	Cover (leatherette)	9.74	3,206	360,000
Sofa	LC16-B	Foam	0.00	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	LC16-C	Lining	9.28	0.00	0.00
Sofa	LC16-D	Foam	429	0.00	0.00
Sofa	LC16-E	Foam	5.54	0.00	0.00
Sofa	LC16-F	Wadding	11.2	129	0.00
Sofa	LC17-A	Lining	1,337	98.6	0.00
Sofa	LC17-B	Cover (textile)	61,787	11,834	0.00
Sofa	LC17-C	Foam	3,338	60.8	0.00
Sofa	LC17-D	Foam	3,124	0.00	0.00
Sofa	LC17-E	Wadding	135	205	0.00
Sofa	LC17-F	Cover (textile)	703	283	0.00
Sofa	LC17-G	Lining	106	0.00	0.00
Sofa	LC18-A	Cover (textile)	27,089	35,988	0.00
Sofa	LC18-B	Cover (textile)	32,165	39,755	0.00
Sofa	LC18-C	Wadding	7.45	0.00	0.00
Sofa	LC18-D	Foam	64.6	0.00	0.00
Sofa	LC18-E	Wadding	259	220	0.00
Sofa	LC19-A	Cover (textile)	257	20,990	0.00
Sofa	LC19-B	Foam	12.9	0.00	0.00
Other	LC20-A	Cover (leatherette)	38.0	2,301	0.00
Other	LC20-B	Wadding	0.00	88.1	0.00
Other	LC20-C	Foam	0.00	0.00	0.00
Sofa	LC21-A	Cover (leatherette)	0.00	4,014	360,000
Sofa	LC21-B	Lining	8.35	0.00	0.00
Sofa	LC21-C	Lining	4.20	73.8	0.00
Sofa	LC21-D	Foam	8.75	0.00	0.00
Sofa	LC22-A	Cover (textile)	81,067	34,673	0.00
Sofa	LC22-B	Lining	310	145	0.00
Sofa	LC22-C	Lining	26.9	0.00	0.00
Sofa	LC22-D	Foam	16,733	529	0.00
Sofa	LC22-E	Wadding	8.35	175	0.00
Sofa	LC24-A	Cover (leatherette)	18.0	116	360,000
Sofa	LC24-B	Foam	7.56	0.00	0.00
Sofa	LC25-A	Cover (leatherette)	18.3	2,680	360,000
Sofa	LC25-B	Cover (leatherette)	11.2	1,561	360,000
Sofa	LC25-C	Foam	0.00	0.00	0.00
Sofa	LC26-A	Cover (textile)	703	130	0.00
Sofa	LC26-B	Foam	34.4	0.00	0.00
Sofa	LC26-C	Foam	19,680	0.00	0.00
Sofa	LC26-D	Lining	22.1	105	0.00
Armchair	LC28-A	Cover (leather)	26.8	0.00	0.00
Armchair	LC28-B	Cover (leatherette)	11.4	3,790	360,000

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Armchair	LC28-C	Foam	2,743	297	0.00
Armchair	LC28-D	Lining	575	0.00	0.00
Armchair	LC28-E	Foam	37.7	0.00	0.00
Armchair	LC28-F	Wadding	14.5	163	0.00
Armchair	LC28-G	Wadding	11.3	98.5	0.00
Armchair	LC28-H	Wadding	8.01	94.1	0.00
Sofa	LC29-A	Cover (leatherette)	40,309	12,422	0.00
Sofa	LC29-B	Foam	42.3	0.00	0.00
Sofa	LC29-C	Wadding	2,553	335	0.00
Dining chair	LC30-A	Cover (leatherette)	25.0	6,253	360,000
Dining chair	LC30-B	Wadding	0.00	174	0.00
Dining chair	LC30-C	Foam	0.00	0.00	0.00
Dining chair	LC30-D	Foam	18.0	0.00	0.00
Armchair	LC31-A	Cover (textile)	25.6	20,587	0.00
Armchair	LC31-B	Foam	40.9	0.00	0.00
Armchair	LC31-C	Foam	23.1	0.00	0.00
Armchair	LC31-D	Foam	6,622	0.00	0.00
Office chair	LC32-A	Cover (leatherette)	0.00	8,884	0.00
Office chair	LC32-B	Cover (textile)	0.00	5,232	0.00
Office chair	LC32-C	Wadding	0.00	143	0.00
Office chair	LC32-D	Foam	255	0.00	0.00
Office chair	LC32-E	Lining	2,879	1,083	0.00
Armchair	LC33-A	Cover (textile)	4.73	46.6	0.00
Armchair	LC33-B	Foam	3,365	190	0.00
Armchair	LC33-C	Lining	35.0	122	0.00
Armchair	LC33-D	Wadding	0.00	131	0.00
Armchair	LC33-E	Foam	24.6	0.00	0.00
Armchair	LC33-F	Foam	13.3	0.00	0.00
Armchair	LC33-G	Cover (textile)	94,966	11,753	0.00
Armchair	LC33-H	Lining	27.2	0.00	0.00
Armchair	LC35-A	Cover (leatherette)	0.00	440	0.00
Armchair	LC35-B	Lining	10.6	0.00	0.00
Armchair	LC35-C	Foam	4,666	0.00	0.00
Armchair	LC35-D	Lining	2,454	700	0.00
Armchair	LC36-A	Cover (leather)	25.2	0.00	0.00
Armchair	LC36-B	Foam	4.95	158	0.00
Armchair	LC36-C	Lining	7.68	0.00	0.00
Armchair	LC36-D	Foam	12.6	0.00	0.00
Sofa	LC37-A	Cover (leather)	333	0.00	0.00
Sofa	LC37-B	Wadding	162	98.7	0.00
Sofa	LC37-C	Foam	31.5	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	LC37-D	Lining	3,420	342	0.00
Sofa	LC38-A	Cover (leather)	2,598	0.00	0.00
Sofa	LC38-B	Foam	14.9	187	0.00
Sofa	LC38-C	Foam	13,621	0.00	0.00
Sofa	LC38-D	Foam	12,988	0.00	0.00
Sofa	LC38-E	Lining	9.93	0.00	0.00
Sofa	LC39-A	Cover (textile)	55,745	23,724	0.00
Sofa	LC39-B	Foam	290	66.9	0.00
Sofa	LC40-A	Cover (leatherette)	46.8	1,473	360,000
Sofa	LC40-B	Cover (leatherette)	140	9,058	0.00
Sofa	LC40-C	Wadding	12.9	197	0.00
Sofa	LC40-D	Wadding	0.00	108	0.00
Armchair	LC41-A	Cover (leather)	131	0.00	0.00
Armchair	LC41-B	Lining	12.8	54.2	0.00
Armchair	LC41-C	Wadding	15.8	99.8	0.00
Armchair	LC41-D	Lining	244	148	0.00
Armchair	LC41-E	Foam	14.5	0.00	0.00
Armchair	LC42-A	Cover (textile)	37,316	10,286	0.00
Armchair	LC42-B	Foam	306	138	0.00
Armchair	LC42-C	Lining	76.0	108	0.00
Sofa	LC43-A	Cover (leather)	298	0.00	0.00
Sofa	LC43-B	Lining	1,472	260	0.00
Sofa	LC43-C	Foam	28.5	0.00	0.00
Sofa	LC43-D	Wadding	72.8	98.7	0.00
Armchair	LC44-A	Cover (leatherette)	13.2	2,740	360,000
Armchair	LC44-B	Lining	8.36	65.0	0.00
Armchair	LC44-C	Foam	17.7	169	0.00
Armchair	LC44-D	Foam	13,499	0.00	0.00
Armchair	LC44-E	Foam	11.8	0.00	0.00
Armchair	LC45-A	Cover (leatherette)	30.2	0.00	0.00
Armchair	LC45-B	Foam	16.2	0.00	0.00
Armchair	LC45-C	Lining	289	74.8	0.00
Sofa	LC46-A	Cover (textile)	79,768	18,945	0.00
Sofa	LC46-B	Lining	85.9	63.5	0.00
Sofa	LC46-C	Foam	28.6	0.00	64,999
Sofa	LC46-D	Foam	829	101	0.00
Sofa	LC47-A	Cover (textile)	29,261	5,253	0.00
Sofa	LC47-B	Foam	93.6	0.00	0.00
Dining chair	LC48-A	Cover (leatherette)	0.00	2,392	0.00
Dining chair	LC48-B	Foam	701	0.00	0.00
Other	LC49-A	Cover (textile)	57,527	5,817	0.00

Category	Code	Sub-category	XRF concentration mg kg⁻¹		
			Br	Sb	Cl
Other	LC49-B	Cover (textile)	100	73.4	0.00
Other	LC49-C	Lining	80.7	66.7	0.00
Other	LC49-D	Lining	10.7	102	0.00
Other	LC49-E	Foam	33.3	0.00	0.00
Sofa	LC50-A	Cover (leather)	60.7	0.00	0.00
Sofa	LC50-B	Wadding	0.00	115	0.00
Sofa	LC50-C	Foam	23.4	0.00	0.00
Armchair	LC51-A	Cover (leatherette)	24.3	0.00	0.00
Armchair	LC51-B	Wadding	161	123	0.00
Armchair	LC51-C	Lining	1,690	514	0.00
Armchair	LC51-D	Wadding	0.00	148	0.00
Sofa	LC52-A	Cover (leather)	129	0.00	0.00
Sofa	LC52-B	Lining	4,598	772	0.00
Sofa	LC52-C	Lining	862	1,400	0.00
Sofa	LC52-D	Wadding	24.3	141	0.00
Sofa	LC53-A	Cover (textile)	31,459	6,410	0.00
Sofa	LC53-B	Cover (textile)	67,288	5,174	0.00
Sofa	LC53-C	Foam	760	0.00	0.00
Sofa	LC53-D	Cover (textile)	34,858	9,766	0.00
Armchair	LC54-A	Cover (textile)	70,694	6,545	0.00
Armchair	LC54-B	Wadding	0.00	139	0.00
Armchair	LC55-A	Cover (leatherette)	12.9	0.00	0.00
Armchair	LC55-B	Foam	6.90	0.00	0.00
Armchair	LC55-C	Foam	6.53	0.00	0.00
Dining chair	LC56-A	Cover (textile)	10.6	0.00	0.00
Dining chair	LC56-B	Wadding	0.00	0.00	0.00
Sofa	HH1-A	Cover (textile)	42.1	0.00	0.00
Sofa	HH1-B	Foam	10,180	0.00	0.00
Sofa	HH1-C	Lining	8.08	107	0.00
Sofa	HH2-A	Cover (leatherette)	75,072	23,254	0.00
Sofa	HH2-B	Wadding	3,411	222	0.00
Sofa	HH2-C	Foam	115	58.3	0.00
Armchair	HH3-A	Cover (textile)	3.01	0.00	0.00
Armchair	HH3-B	Lining	7.92	63.3	0.00
Armchair	HH3-C	Wadding	8.58	104	0.00
Armchair	HH3-D	Foam	0.00	0.00	0.00
Armchair	HH4-A	Cover (leather)	55.6	0.00	0.00
Armchair	HH4-B	Wadding	58.8	129	0.00
Armchair	HH4-C	Foam	4,609	0.00	0.00
Sofa	HH5-A	Cover (leather)	50.8	0.00	0.00
Sofa	HH5-B	Foam	14.7	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	HH6-A	Cover (leatherette)	29,505	9,889	0.00
Sofa	HH6-B	Wadding	620	133	0.00
Sofa	HH6-C	Foam	105	0.00	0.00
Sofa	HH6-D	Foam	12.9	0.00	0.00
Sofa	HH6-E	Lining	5,332	1,635	0.00
Sofa	HH7-A	Cover (textile)	7,483	1,510	0.00
Sofa	HH7-B	Foam	7.24	0.00	0.00
Sofa	HH8-A	Cover (textile)	151	116	0.00
Sofa	HH8-B	Wadding	8.01	113	0.00
Other	HH9-A	Cover (textile)	19,397	8,956	0.00
Other	HH9-B	Foam	21.3	0.00	0.00
Armchair	HH10-A	Cover (textile)	34,774	13,429	0.00
Armchair	HH10-B	Foam	1,887	113	0.00
Sofa	HH11-A	Cover (textile)	51,520	8,811	0.00
Sofa	HH11-B	Lining	2,405	90.6	0.00
Sofa	HH11-C	Wadding	243	153	0.00
Dining chair	HH12-A	Cover (textile)	8.23	0.00	0.00
Dining chair	HH12-B	Wadding	13.1	0.00	0.00
Dining chair	HH12-C	Wadding	11.2	0.00	0.00
Armchair	HH13-A	Cover (leather)	21.8	0.00	0.00
Armchair	HH13-B	Wadding	0.00	134	0.00
Armchair	HH13-C	Lining	14.7	122	0.00
Armchair	HH13-D	Foam	10.6	0.00	360,000
Sofa	HH14-A	Cover (textile)	31,354	14,324	0.00
Sofa	HH14-B	Foam	114	0.00	0.00
Sofa	HH14-C	Wadding	764	195	0.00
Sofa	HH15-A	Cover (textile)	50,082	6,366	0.00
Sofa	HH15-B	Lining	3,986	159	0.00
Sofa	HH15-C	Wadding	383	179	0.00
Sofa	HH15-D	Lining	64.1	0.00	0.00
Sofa	HH16-A	Cover (leatherette)	5.82	49.9	0.00
Sofa	HH16-B	Foam	0.00	0.00	360,000
Sofa	HH17-A	Cover (textile)	20.0	65.4	0.00
Sofa	HH17-B	Wadding	6.64	146	0.00
Sofa	HH17-C	Lining	14.9	0.00	0.00
Sofa	HH18-A	Cover (leather)	102	0.00	0.00
Sofa	HH18-B	Lining	1,881	1,284	0.00
Sofa	HH18-C	Wadding	43.8	0.00	0.00
Sofa	HH18-D	Foam	37.7	0.00	0.00
Sofa	HH18-E	Lining	11,045	2,514	0.00
Sofa	HH19-A	Cover (textile)	69,773	11,024	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	HH19-B	Lining	3,108	198	0.00
Sofa	HH19-C	Wadding	338	226	0.00
Sofa	HH19-D	Lining	167	0.00	0.00
Sofa	HH20-A	Cover (leather)	11.3	0.00	0.00
Sofa	HH20-B	Foam	228	0.00	0.00
Sofa	HH20-C	Lining	23.9	0.00	0.00
Sofa	HH20-D	Lining	20.7	0.00	0.00
Sofa	HH21-A	Cover (leather)	9.97	0.00	0.00
Sofa	HH21-B	Foam	23.0	0.00	0.00
Sofa	HH21-C	Lining	13.9	0.00	0.00
Sofa	HH22-A	Cover (leatherette)	35,710	4,033	0.00
Sofa	HH22-B	Foam	161	0.00	0.00
Sofa	HH23-A	Cover (leatherette)	0.00	2,084	360,000
Sofa	HH23-B	Foam	8.66	0.00	0.00
Sofa	HH23-C	Lining	7.92	0.00	0.00
Sofa	HH24-A	Cover (leather)	28.0	0.00	0.00
Sofa	HH24-B	Wadding	34.1	145	0.00
Sofa	HH24-C	Foam	39.1	0.00	0.00
Armchair	HH25-A	Cover (textile)	20,984	2,267	0.00
Armchair	HH25-B	Foam	202	0.00	0.00
Sofa	HH26-A	Cover (textile)	57,113	8,492	0.00
Sofa	HH26-B	Foam	2,951	216	0.00
Sofa	HH27-A	Cover (leather)	56.3	0.00	0.00
Sofa	HH27-B	Foam	13.1	0.00	360,000
Armchair	HH28-A	Cover (leatherette)	0.00	0.00	360,000
Armchair	HH28-B	Lining	16.8	80.9	0.00
Armchair	HH28-C	Wadding	12.1	0.00	0.00
Armchair	HH28-D	Misc.	9.70	0.00	0.00
Sofa	HH29-A	Cover (textile)	22.0	0.00	0.00
Sofa	HH29-B	Wadding	17.7	146	0.00
Sofa	HH29-C	Foam	18.9	0.00	0.00
Sofa	HH30-A	Cover (leatherette)	26.1	2,353	360,000
Sofa	HH30-B	Foam	38.5	0.00	0.00
Sofa	HH30-C	Misc.	32.0	140	0.00
Sofa	HH30-D	Wadding	0.00	172	0.00
Sofa	HH31-A	Cover (textile)	0.00	0.00	0.00
Sofa	HH31-B	Lining	0.00	0.00	0.00
Sofa	HH31-C	Foam	0.00	0.00	0.00
Sofa	HH31-D	Wadding	0.00	127	0.00
Armchair	HH32-A	Cover (leather)	92.8	0.00	0.00
Armchair	HH32-B	Wadding	337	105	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Armchair	HH32-C	Foam	20,580	0.00	0.00
Armchair	HH32-D	Foam	200	0.00	0.00
Armchair	HH33-A	Cover (textile)	9.89	0.00	0.00
Armchair	HH33-B	Foam	255	46,663	360,000
Armchair	HH33-C	Lining	11.3	0.00	0.00
Armchair	HH33-D	Foam	0.00	0.00	0.00
Armchair	HH34-A	Cover (textile)	45.5	0.00	0.00
Armchair	HH34-B	Lining	121	70.9	0.00
Armchair	HH34-C	Foam	20,740	0.00	0.00
Sofa	HH35-A	Cover (textile)	0.00	0.00	0.00
Sofa	HH35-B	Lining	0.00	0.00	0.00
Sofa	HH35-C	Foam	14.6	0.00	0.00
Sofa	HH35-D	Wadding	0.00	139	0.00
Armchair	HH36-A	Cover (leather)	34.3	0.00	0.00
Armchair	HH36-B	Lining	4.66	54.1	0.00
Armchair	HH36-C	Lining	0.00	0.00	0.00
Armchair	HH36-D	Wadding	0.00	116	0.00
Armchair	HH36-E	Foam	16.3	0.00	0.00
Armchair	HH36-F	Foam	12.2	0.00	0.00
Sofa	HH37-A	Cover (leatherette)	298	2,889	360,000
Sofa	HH37-B	Foam	6.21	0.00	0.00
Sofa	HH38-A	Cover (leather)	22.9	0.00	0.00
Sofa	HH38-B	Lining	0.00	154	0.00
Sofa	HH38-C	Wadding	0.00	91.3	0.00
Sofa	HH38-D	Foam	0.00	0.00	0.00
Sofa	HH39-A	Cover (textile)	35,291	1,901	0.00
Sofa	HH39-B	Foam	2,508	0.00	0.00
Sofa	HH39-C	Lining	130	0.00	0.00
Sofa	HH40-A	Cover (textile)	49,023	11,204	0.00
Sofa	HH40-B	Lining	6,754	315	0.00
Sofa	HH40-C	Wadding	55.1	205	0.00
Other	HH41-A	Cover (textile)	31.7	0.00	0.00
Other	HH41-B	Wadding	35.8	173	0.00
Other	HH41-C	Foam	0.00	0.00	0.00
Other	HH41-D	Lining	38.4	0.00	0.00
Sofa	HH42-A	Cover (textile)	37,802	24,525	0.00
Sofa	HH42-B	Foam	8,785	377	0.00
Sofa	HH42-C	Foam	7,882	0.00	0.00
Sofa	HH42-D	Lining	98.5	0.00	0.00
Sofa	HH43-A	Cover (leather)	29.1	0.00	0.00
Sofa	HH43-B	Lining	11.0	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	HH43-C	Wadding	0.00	150	0.00
Sofa	HH44-A	Cover (leatherette)	24.3	0.00	360,000
Sofa	HH44-B	Foam	278	0.00	0.00
Dining chair	HH45-A	Cover (textile)	57,643	20,950	0.00
Dining chair	HH45-B	Wadding	461	144	0.00
Sofa	HH46-A	Cover (textile)	14,536	2,591	0.00
Sofa	HH46-B	Lining	77.0	98.4	0.00
Sofa	HH46-C	Foam	29.2	0.00	0.00
Other	HH47-A	Cover (textile)	6.71	146	0.00
Other	HH47-B	Lining	0.00	0.00	0.00
Other	HH47-C	Foam	0.00	0.00	0.00
Armchair	HH48-A	Cover (textile)	16.4	0.00	0.00
Armchair	HH48-B	Foam	22.1	0.00	0.00
Sofa	HH49-A	Cover (textile)	59,789	11,083	0.00
Sofa	HH49-B	Foam	47.8	0.00	0.00
Sofa	HH50-A	Cover (textile)	43.3	0.00	0.00
Sofa	HH50-B	Lining	11.3	0.00	0.00
Sofa	HH50-C	Wadding	54.4	170	0.00
Sofa	HH51-A	Cover (textile)	57.4	1,883	360,000
Sofa	HH51-B	Cover (textile)	35.0	0.00	0.00
Sofa	HH51-C	Lining	86.0	186	0.00
Sofa	HH51-D	Foam	73,551	31,204	0.00
Other	HH52-A	Cover (textile)	10,007	1,751	0.00
Other	HH52-B	Wadding	381	211	0.00
Other	HH52-C	Foam	1,312	38.9	360,000
Sofa	HH53-A	Cover (leatherette)	11.6	468	360,000
Sofa	HH53-B	Lining	14.2	0.00	0.00
Sofa	HH53-C	Wadding	15.9	93.9	0.00
Sofa	HH53-D	Misc.	104	51.0	0.00
Sofa	HH53-E	Foam	14,332	0.00	0.00
Sofa	HH54-A	Cover (textile)	22,697	5,665	0.00
Sofa	HH54-B	Lining	410	0.00	0.00
Sofa	HH54-C	Wadding	25.5	143	0.00
Sofa	HH55-A	Cover (leather)	18.8	0.00	0.00
Sofa	HH55-B	Foam	16.1	0.00	0.00
Sofa	HH56-A	Cover (textile)	79,817	14,781	0.00
Sofa	HH56-B	Foam	2,850	186	0.00
Sofa	HH56-C	Foam	255	0.00	0.00
Sofa	HH56-D	Foam	1,500	0.00	0.00
Sofa	HH57-A	Cover (leatherette)	38,808	4,397	0.00
Sofa	HH57-B	Wadding	303	204	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	HH57-C	Foam	65.5	0.00	360,000
Sofa	HH58-A	Cover (leatherette)	16.1	1,895	360,000
Sofa	HH58-B	Wadding	0.00	193	0.00
Sofa	HH59-A	Cover (textile)	59.3	0.00	0.00
Sofa	HH59-B	Wadding	107	149	0.00
Sofa	HH59-C	Foam	20.1	0.00	0.00
Sofa	HH60-A	Cover (textile)	25,186	8,431	0.00
Sofa	HH60-B	Foam	1,671	0.00	0.00
Sofa	HH60-C	Wadding	1,723	192	0.00
Sofa	HH60-D	Foam	1,623	98.4	0.00
Sofa	HH61-A	Cover (textile)	40.1	0.00	0.00
Sofa	HH61-B	Lining	20.5	0.00	0.00
Sofa	HH61-C	Wadding	0.00	182	0.00
Sofa	HH62-A	Cover (leather)	11.0	0.00	0.00
Sofa	HH62-B	Foam	10.1	0.00	0.00
Sofa	HH62-C	Lining	5,038	922	0.00
Sofa	HH62-D	Lining	14,892	2,860	0.00
Sofa	HH62-E	Foam	82.1	0.00	0.00
Sofa	HH63-A	Cover (textile)	20.6	0.00	0.00
Sofa	HH63-B	Lining	40.0	0.00	0.00
Sofa	HH63-C	Foam	10.3	0.00	0.00
Sofa	HH64-A	Wadding	52.5	82.7	0.00
Sofa	HH64-B	Foam	26.6	0.00	0.00
Sofa	HH64-C	Cover (leather)	31,496	3,070	0.00
Sofa	HH64-D	Foam	20.1	0.00	360,000
Sofa	HH64-E	Lining	2,066	655	0.00
Sofa	HH65-A	Cover (textile)	62,428	6,376	0.00
Sofa	HH65-B	Foam	36.4	0.00	0.00
Sofa	HH66-A	Cover (textile)	21.3	0.00	0.00
Sofa	HH66-B	Wadding	0.00	0.00	0.00
Sofa	HH66-C	Lining	3.03	0.00	0.00
Sofa	HH66-D	Wadding	0.00	98.1	0.00
Other	HH67-A	Cover (textile)	413	13,927	0.00
Armchair	HH69-A	Foam	0.00	0.00	0.00
Armchair	HH69-B	Wadding	16.5	113	0.00
Armchair	HH69-C	Cover (textile)	480	57.2	360,000
Dining chair	HH70-A	Cover (textile)	210	147	0.00
Dining chair	HH70-B	Wadding	50.1	125	0.00
Dining chair	HH70-C	Lining	87.5	95.3	0.00
Dining chair	HH70-D	Foam	953	0.00	0.00
Sofa	HH71-A	Cover (textile)	54,847	15,257	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	HH71-B	Wadding	0.00	110	0.00
Sofa	HH71-C	Lining	1,057	125	0.00
Sofa	HH72-A	Cover (textile)	105,060	30,072	0.00
Sofa	HH72-B	Wadding	131	210	0.00
Sofa	HH72-C	Foam	47.4	0.00	0.00
Sofa	HH73-A	Wadding	0.00	90.0	0.00
Sofa	HH73-B	Cover (leatherette)	16,957	909	360,000
Sofa	HH73-C	Lining	27.0	113	0.00
Sofa	HH73-D	Lining	173	0.00	0.00
Sofa	SP1-A	Cover (leather)	446	0.00	0.00
Sofa	SP1-B	Lining	83.4	0.00	0.00
Sofa	SP1-C	Foam	0.00	100	0.00
Sofa	SP2-A	Cover (leather)	36.1	0.00	0.00
Sofa	SP3-A	Cover (textile)	53,558	5,659	0.00
Sofa	SP3-B	Foam	432	148	0.00
Sofa	SP3-C	Lining	90.9	161	0.00
Sofa	SP4-A	Cover (textile)	17,960	1,319	0.00
Sofa	SP4-B	Foam	1,173	83.1	0.00
Sofa	SP5-A	Cover (textile)	20,881	6,037	0.00
Sofa	SP5-B	Lining	300	146	0.00
Sofa	SP5-C	Foam	927	334	0.00
Sofa	SP6-A	Cover (textile)	334	0.00	0.00
Sofa	SP6-B	Foam	0.00	0.00	0.00
Sofa	SP7-A	Cover (textile)	53,604	1,827	0.00
Sofa	SP7-B	Lining	90.8	0.00	0.00
Sofa	SP7-C	Foam	6,599	451	0.00
Sofa	SP7-D	Lining	47.5	0.00	0.00
Sofa	SP8-A	Cover (textile)	82,530	11,951	0.00
Sofa	SP8-B	Lining	190	0.00	0.00
Sofa	SP8-C	Foam	689	139	0.00
Sofa	SP8-D	Wadding	418	111	0.00
Sofa	SP8-E	Lining	21.0	0.00	0.00
Dining chair	SP9-A	Cover (textile)	93.1	0.00	0.00
Office chair	SP10-A	Cover (textile)	7.91	1,396	0.00
Armchair	SP11-A	Cover (textile)	16.6	56.4	0.00
Armchair	SP11-B	Lining	0.00	0.00	0.00
Armchair	SP11-C	Foam	0.00	118	0.00
Armchair	SP12-A	Cover (textile)	25,775	3,389	0.00
Armchair	SP12-B	Lining	128	180	0.00
Armchair	SP12-C	Foam	903	0.00	0.00
Armchair	SP13-A	Cover (leather)	175	0.00	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	SP14-A	Cover (leather)	43.3	34.0	0.00
Sofa	SP15-A	Cover (leather)	33.9	72.3	0.00
Armchair	SP16-A	Cover (textile)	1,932	0.00	0.00
Armchair	SP16-B	Lining	0.00	0.00	0.00
Armchair	SP16-C	Foam	9.96	0.00	0.00
Armchair	SP16-D	Lining	186	0.00	0.00
Sofa	SP17-A	Cover (textile)	6.99	102	0.00
Sofa	SP17-B	Lining	7.49	151	0.00
Armchair	SP18-A	Cover (leather)	245	0.00	0.00
Armchair	SP18-B	Lining	1,063	0.00	0.00
Armchair	SP18-C	Foam	38.7	0.00	0.00
Dining chair	SP19-A	Cover (textile)	24,824	3,777	0.00
Armchair	SP20-A	Cover (textile)	21,527	5,655	0.00
Armchair	SP20-B	Lining	4,278	12,602	360,000
Armchair	SP20-C	Foam	1,121	237	0.00
Armchair	SP21-A	Cover (textile)	47,775	11,097	0.00
Armchair	SP21-B	Lining	3,908	13,314	360,000
Armchair	SP21-C	Foam	1,166	293	0.00
Dining chair	SP22-A	Cover (textile)	34.4	0.00	0.00
Dining chair	SP22-B	Lining	4.99	0.00	0.00
Sofa	SP23-A	Cover (leather)	24.5	40.8	0.00
Sofa	SP24-A	Cover (textile)	21.4	0.00	0.00
Sofa	SP24-B	Lining	9.49	74.5	0.00
Sofa	SP24-C	Foam	0.00	63.6	0.00
Sofa	SP25-A	Cover (textile)	9,925	2,690	0.00
Sofa	SP25-B	Lining	332	0.00	0.00
Sofa	SP25-C	Foam	28.4	0.00	0.00
Sofa	SP26-A	Cover (textile)	16,129	3,556	0.00
Sofa	SP26-B	Lining	274	172	0.00
Sofa	SP26-C	Foam	4,319	126	0.00
Armchair	SP27-A	Cover (textile)	196	805	0.00
Armchair	SP27-B	Lining	15.8	0.00	0.00
Armchair	SP27-C	Foam	26.9	0.00	0.00
Sofa	SP28-A	Cover (leather)	125	0.00	0.00
Sofa	SP29-A	Cover (textile)	21,281	3,594	0.00
Sofa	SP29-B	Lining	141	0.00	0.00
Sofa	SP29-C	Foam	2,026	208	0.00
Sofa	SP30-A	Cover (textile)	25,101	3,960	0.00
Sofa	SP30-B	Lining	148	181	0.00
Sofa	SP31-A	Cover (textile)	6,387	3,080	0.00
Armchair	SP32-A	Cover (textile)	56,539	6,053	0.00

Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Armchair	SP32-B	Foam	4,571	375	0.00
Sofa	SP33-A	Cover (leather)	41.0	0.00	0.00
Sofa	SP33-B	Lining	243	157	0.00
Sofa	SP33-C	Foam	0.00	139	0.00
Armchair	SP34-A	Cover (leather)	25.0	0.00	0.00
Armchair	SP34-B	Lining	0.00	0.00	0.00
Armchair	SP34-C	Foam	0.00	0.00	0.00
Sofa	SP35-A	Cover (leatherette)	46.4	2,735	360,000
Sofa	SP35-B	Lining	19.3	0.00	0.00
Sofa	SP35-C	Foam	0.00	145	0.00
Armchair	SP36-A	Cover (leatherette)	44.4	2,814	360,000
Armchair	SP36-B	Lining	0.00	58.2	0.00
Armchair	SP36-C	Foam	0.00	134	0.00
Other	SP37-A	Cover (leather)	0.00	3,010	360,000
Dining chair	SP38-A	Cover (leather)	951	0.00	0.00
Dining chair	SP38-B	Lining	104	0.00	0.00
Dining chair	SP39-A	Cover (textile)	0.00	0.00	0.00
Dining chair	SP39-B	Lining	0.00	0.00	0.00
Dining chair	SP39-C	Foam	0.00	0.00	0.00
Armchair	SP40-A	Cover (textile)	56,132	16,235	0.00
Armchair	SP40-B	Lining	28.0	5,352	360,000
Armchair	SP40-C	Foam	267	0.00	0.00
Armchair	SP41-A	Cover (textile)	32,354	15,687	0.00
Armchair	SP42-A	Cover (textile)	53.3	857	0.00
Armchair	SP42-B	Lining	0.00	0.00	0.00
Armchair	SP42-C	Foam	103	728	360,000
Sofa	SP43-A	Cover (textile)	8.52	0.00	0.00
Sofa	SP43-B	Lining	19.2	0.00	0.00
Sofa	SP43-C	Foam	0.00	0.00	0.00
Dining chair	SP44-A	Cover (leather)	438	0.00	0.00
Dining chair	SP44-B	Lining	150	0.00	0.00
Sofa	SP45-A	Cover (leather)	41.2	0.00	0.00
Sofa	SP45-B	Lining	685	143	0.00
Sofa	SP45-C	Foam	8.20	0.00	0.00
Sofa	SP46-A	Cover (textile)	63,909	2,299	0.00
Sofa	SP46-B	Lining	99.0	132	0.00
Sofa	SP46-C	Foam	771	197	0.00
Dining chair	SP47-A	Cover (textile)	15,878	1,870	0.00
Dining chair	SP47-B	Foam	48.2	0.00	0.00
Sofa	SP48-A	Cover (textile)	41,694	13,248	0.00
Sofa	SP48-B	Lining	143	0.00	0.00

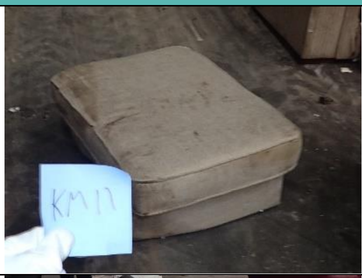
Category	Code	Sub-category	XRF concentration mg kg^{-1}		
			Br	Sb	Cl
Sofa	SP48-C	Foam	994	258	0.00
Armchair	SP49-A	Cover (leather)	10.9	57.1	0.00
Sofa	SP50-A	Cover (leather)	12.8	0.00	0.00
Armchair	SP51-A	Cover (leather)	24.2	0.00	0.00
Armchair	SP51-B	Cover (textile)	165	147	0.00
Armchair	SP51-C	Lining	254	0.00	0.00
Armchair	SP51-D	Foam	0.00	167	0.00
Armchair	SP52-A	Cover (textile)	13,066	4,580	0.00
Armchair	SP52-B	Lining	206	131	0.00
Armchair	SP52-C	Foam	521	0.00	0.00
Sofa	SP53-A	Cover (leather)	17.0	0.00	0.00
Sofa	SP53-B	Lining	402	0.00	0.00
Sofa	SP53-C	Foam	7.91	0.00	0.00
Dining chair	SP54-A	Cover (textile)	8.16	2,833	0.00
Dining chair	SP54-B	Lining	0.00	0.00	0.00
Office chair	SP55-A	Cover (textile)	30.5	0.00	0.00
Office chair	SP55-B	Lining	0.00	0.00	0.00
Sofa	SP56-A	Cover (leather)	18.9	0.00	0.00
Sofa	SP57-A	Cover (leather)	22.7	50.3	0.00
Sofa	SP58-A	Cover (leather)	35.5	49.4	0.00
Sofa	SP59-A	Cover (leather)	570	119	0.00
Sofa	SP59-B	Lining	4,686	62.7	0.00
Sofa	SP59-C	Foam	737	67.4	0.00
Dining chair	SP60-A	Cover (textile)	20,115	2,575	0.00
Dining chair	SP60-B	Lining	5.95	0.00	0.00
Dining chair	SP61-A	Cover (leather)	10.7	0.00	0.00
Dining chair	SP61-B	Lining	5.86	0.00	0.00
Office chair	SP62-A	Cover (textile)	23.8	0.00	0.00
Office chair	SP62-B	Lining	5.49	0.00	0.00
Office chair	SP63-A	Cover (textile)	21.8	0.00	0.00
Dining chair	SP64-A	Cover (textile)	20,507	5,327	0.00
Dining chair	SP64-B	Lining	10.9	0.00	0.00

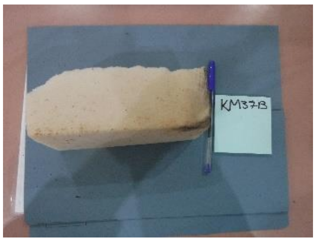
Appendix D Laboratory Analytical Testing

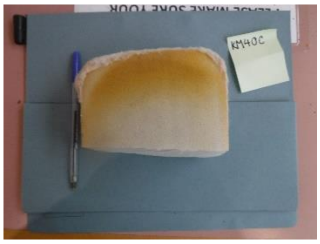
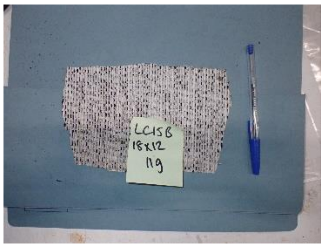
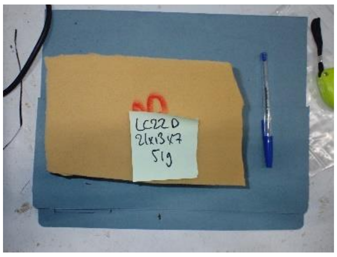
D1 Samples Submitted for Quantitative Chemical Testing

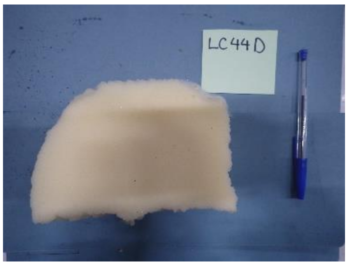
The samples which were sent for Tier 3 testing are shown in Table D.1. The samples are shown alongside their 'source item' i.e. sofa, arm chair etc.

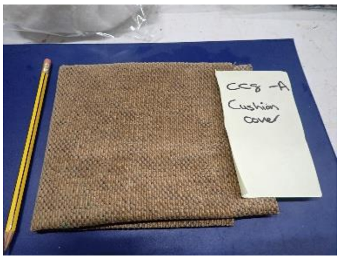
Table D.1 Tier 3 sample description and photographs

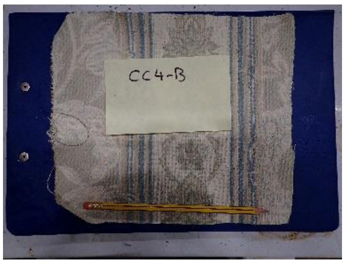
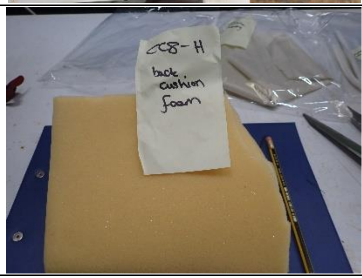
Sample information	Item	Component
W9078 - EA-KM11-D Other (footstool) Cover (textile) Bromine (9.86%)		
W9079 - EA-KM12-E Armchair (club) Lining (textile) Bromine (0.45%)		
W9080 - EA-KM16-A Sofa (unknown size) Cover (textile) Bromine (9.64%)		
W9081 - EA-KM17-A Sofa (unknown size) Cover (textile) Bromine (6.31%)		

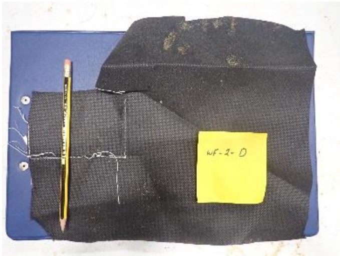
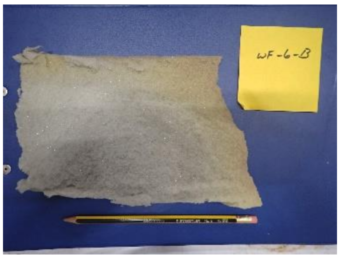
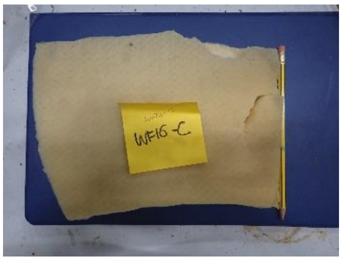
Sample information	Item	Component
W9082 - EA-KM17-B Sofa (unknown size) Foam Bromine (0.47%)		
W9083 - EA-KM20-C Sofa (unknown size) Foam Bromine (1.47%)		
W9084 - EA-KM22-A Armchair (unknown shape) Cover (leatherette) Bromine (11.5%)		
W9085 - EA-KM22-B Armchair (unknown shape) Cover (textile) Bromine (6.7%)		
W9086 - EA-KM26-D Armchair (unknown shape) Foam Bromine (1.7%)		
W9087 - EA-KM37-B Other (footstool) Foam Bromine (1.2%)		

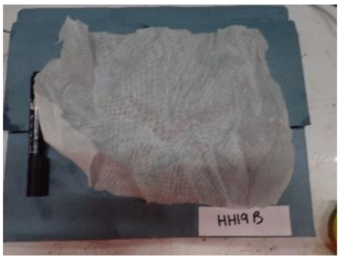
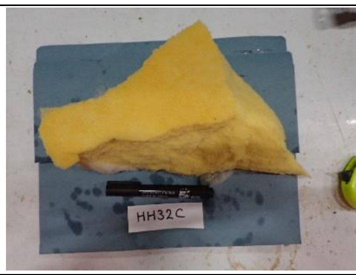
Sample information	Item	Component
W9088 - EA-KM40-C Sofa Foam Bromine (1.6%)		
W9090 - EA-LC15-B Sofa Cover (textile) Bromine (10.5%)		
W9091 - EA-LC22-A Sofa Cover (textile) Bromine (8.1%)		
W9092 - EA-LC22-D Sofa Foam Bromine (1.7%)		
W9093 - EA-LC26-C Sofa Foam Bromine (2.0%)		
W9094 - EA-LC7-D Chair Lining Bromine (0.9%)		

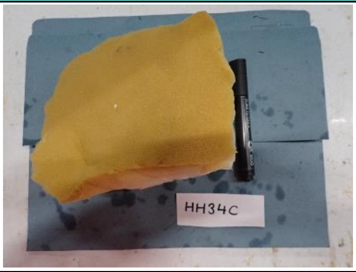
Sample information	Item	Component
W9095 - EA-LC29-A Sofa Cover (leatherette) Bromine (4.0%)		
W9096 - EA-LC33-G Armchair Cover (textile) Bromine (9.5%)		
W9097 - EA-LC38-C Sofa Foam Bromine (1.4%)		
W9098 - EA-LC38-D Sofa Foam Bromine (1.3%)		
W9099 - EA-LC44-D Armchair Foam Bromine (1.3%)		
W9020 - EA-CC17-A Sofa Cover (textile)		No image available.

Sample information	Item	Component
W9021 - EA-CC17-B Sofa Foam Bromine (0.8%)		No image available.
W9022 - EA-CC8-A Armchair Cover (textile) Bromine (6.3%)		
W9023 - EA-CC23-B Armchair Cover (textile) Bromine (3.6%)		
W9024 - EA-CC23-D Armchair Lining Bromine (0.9%)		
W9025 - EA-CC27-B Sofa Cover (textile) Bromine (3.3%)		
W9026 - EA-CC25-B Sofa Cover (textile) Bromine (4.5%)		

Sample information	Item	Component
W9027 - EA-CC4-B Armchair Cover (textile) Bromine (5.3%)		
W9028 - EA-CC6-A Chair Cover (textile) Bromine (6.1%)		
W9029 - EA-CC11-B Sofa Cover (textile) Bromine (4.1%)		
W9030 - EA-CC8-H Armchair Foam Bromine (0.5%)		
W9031 - EA-CC5-C Sofa Foam Bromine (0.6%)		
W9032 - EA-WF2-A Chair Cover (leatherette) Bromine (2.3%)		

Sample information	Item	Component
W9033 - EA-WF2-D Chair Lining Bromine (0.8%)		
W9034 - EA-WF6-B Chair Foam Bromine (1.8%)		
W9036 - EA-WF16-A Sofa Cover (leatherette) Bromine (6.9%)		
W9036 - EA-WF16-B Sofa Cover (textile) Bromine (7.0%)		
W9037 - EA-WF16-C Sofa Foam Bromine (0.6%)		
W9038 - EA-WF24-A Armchair Cover (textile) Bromine (8.9%)		

Sample information	Item	Component
W9039 - EA-WF9-A Footstool Cover (textile) Bromine (3.6%)		
W9169 - EA-HH19-A Sofa Cover (textile) Bromine (7.0%)		
W9170 - EA-HH19-B Sofa Lining Bromine (0.3%)		
W9171 - EA-HH2-A Sofa Cover (leatherette) Bromine (7.5%)		
W9172 - EA-HH22-A Sofa Cover (leatherette) Bromine (3.6%)		
W9173 - EA-HH32-C Armchair Foam Bromine (2.1%)		

Sample information	Item	Component
W9174 - EA-HH34-C Armchair Foam Bromine (2.0%)		
W9175 - EA-HH51-D Sofa Foam Bromine (7.4%)		
W9176 - EA-HH56-A Sofa Cover (textile) Bromine (8.0%)		
W9177 - EA-HH72-A Sofa Cover (textile) Bromine (10.5%)		

D2 Details of Sub-contract Laboratory Experience and Test Methods

D2.1 Tier 2 screening - Amsterdam

Screening tests were sub-contracted to the Institute for Environmental Studies (IVM), VU University Amsterdam, de Boelelaan 1087, 1081 HV Amsterdam in The Netherlands. IVM are the oldest environmental research institute in The Netherlands (established in 1971), and is rated with high scores on scientific excellence. They have significant experience of undertaking traditional quantitative analysis on flame retardants in a wide range of matrices. Of specific relevance to this project is a semi-quantitative broad range screening tool that has been developed to asess the presence of a wide range of flame retardants and additives in polymer plastics and other matrices. They have published a substantial number of technical papers in recognised scientific journals and worked with research institutes world-wide in the completion of this work.

Pre-milled samples were extracted with toluene using sonication, followed by 2-propanol and another sonication step. For the extraction of BDE209 toluene alone was used due to poor recovery using 2-propanol. The extracts were centrifuged and a small amount, in triplicate, is added to an atmospheric pressure matrix-assisted laser desorption ionization (AP-MALDI) plate. Final measurements are performed with an AP-MALDI source (MassTech, AP-MALDI (ng) UHR) coupled to a high-resolution quadrupole time-of-flight (qTOF Compact Bruker) mass spectrometer, except for BDE209, which was measured with LC-APCI-QTOFMS in negative mode. Identification of the chemicals is based on the exact mass and isotope patterns and were compared to analytical standards, see below. Identification was performed on confidence level 4 according to the scheme of Schymanski et al. 2014. QA measures include duplicate analysis of a number of samples, procedural blanks, use of an intern reference material (foam), and the analyses of analytical standards (SCCPs, PBDEs, HBCDD, phthalates, PFRs, TBBP-A, Cl-PFRs, and Br-PFRs). The average sample-to-sample relative standard deviation (RSDs) is less than <25 %. The limit of detection is about 0.1% of the product analysed.

D2.2 Tier 3 semi-quantitative and quantitative analysis - Fraunhofer Institute

The Fraunhofer Institute for Process Engineering and Packaging (Fraunhofer IVV) based in Giggenhauser Str. 35, 85354 Freising, Germany was substracted to undertake the quantitative testing of PBDEs and other flames retardents in domestic seating. The project team are focussed on recycling and the environment, and use state of the art analytical equipment to developing test methods for flame retardant chemicals in a variety of different matrices. Many of these methods have been published in the scientific literature and include the measurement of PBDEs in air, dust, and polymer matrices.

Fraunhofer IVV operate a quality management system which meets the requirements of DIN EN ISO/IEC 17025: 2018 and hence also the requirements of ISO 9001:2015 for the test laboratories.

D2.2.1 Laboratory experience in analysis of decaBDE and HBCDD in waste

Fraunhofer IVV has considerable experience in the analysis of FR in waste matrices and in particular PBDEs through involvement in various studies since 1999. Fraunhofer adopt a flexible approach to test for these chemicals and adapt the method according to the analytical needs and matrices using techniques including gas chromatography (GC)-quadrupole mass spectrometry (MS), gas chromatography – high resolution mass spectrometry (GC-HRMS), HPLC-Electron Capture Detection(ECD)-HRMS, liquid chromatography – high resolution mass spectrometry (LC-HRMS) and X-ray fluorescence (XRF). Fraunhofer IVV is recognised as a world leader in PBDE analysis. It has been involved in pan-European interlaboratory assessments for PBDE analysis to ensure quality. They have also taken a lead in PBDE method development and have published several scientific articles in this field:

- Schlummer et al. (2002), Recycling of technical polymers from electronic waste while eliminating brominated flame retardants and PBDD/F, Organohal. Compds.
- Schlummer et al. (2005), Analysis of flame retardant additives in polymer fractions of waste of electric and electronic equipment (WEEE) by means of HPLC-UV/MS and GPC-HPLC-UV, Journal of Chromatography A.
- Cleres et al. (2009), Parallel pressurized solvent extraction of PCDD/PCDF, PBDE, and PFC from soil, sludge, and sediment samples, Organohal. Compds.
- Schlummer et al. (2015), Rapid identification of PS foam wastes containing HBCDD or its alternative PolyFR by X-ray fluorescence spectroscopy (XRF), Waste Management & Research.
- Sinduku et al (2015)., Polybrominated diphenyl ethers listed as Stockholm Convention POPs, other brominated flame retardants and heavy metals in e-waste polymers in Nigeria, Environmental science and pollution research international.
- Schlummer et al. (2017), Recycling of flame retarded waste polystyrene foams (EPS and XPS) to PS granules free of hexabromocyclododecane (HBCDD), Advances in Recycling & Waste Management.

Fraunhofer use different extraction solvents depending on the test matrix, which include toluene, tetrahydrofuran (THF) and iso-propanol to ensure optimum extraction of PBDEs and other flame retardants. The extraction methods are assessed using XRF to estimate the extraction efficiency of the process which can give an indication on the limitation of the technique and the mass balance of an atomic compound. This can also provide an insight as to whether the brominated flame retardants are chemically bound to the polymer matrix (backbone flame retardants) or are mobile within the matrix (matrix flame retardants).

The analytical methods have undergone appropriate method development for POPs. An important part of the method development is the use of isotope labelled standards. Fraunhofer have incorporated the development of new analytical methods for the analysis of contaminants into the quality management system (DIN EN ISO/IEC 17025). Their expertise in method development was confirmed by the re-accreditation body in 2000, 2006, 2011, 2012, 2016.

D2.2.2 Quality control and assurance methods

Quality control and assurance were undertaken according to DIN EN ISO/IEC 17025 and included the use of a preliminary bromine screening using XRF during the clean-up step to predict dilution steps and the use of internal standards ("isotope dilution"). This approach allowed for recoveries (extraction efficiencies) and limits of detection (LODs) for each individual sample to be estimated.

Alongside the use of XRF during the clean-up step, XRF of the post extraction residues was also undertaken. To undertake the XRF analysis, the subsamples were filled in plastic cuvettes lined with 12µm Prolene® film and subjected to a measurement using a Spectro XEPOS bench-top XRF instrument using the standard method for plastics. LODs of the energy dispersive XRF (ED-XRF) method are less than 10 mg/kg with this setup.

An important quality control step also included the analysis of sufficient blank samples. The use of GC-HRMS enabled Fraunhofer to perform the analysis selectively with strict observation of the bromine isotopic ratios. This reduced the potential for extraction overlap of different PBDE congeners which can cause either over-estimation or underestimatiom of concentration.

The quality control methods used in this work indicated that the intial extractions were unable to characterise or identify all bromine containing substances in the samples. Therefore additional experiments were preformed to determine whether alternative brominated compounds were present and therefore may clarify the discrepency between initial LC and GC-MS results and XRF data. As well as the testing for alternative brominated compounds the additional analysis included phosphorous-based flame retardants which may have caused interference in the initial extraction process. This information supported the use of an alternative extraction method to determine the decaBDE concentration in some samples where suspected interference was at play.

D2.2.3 PBDEs and HBCDD

ASE extraction

Extraction and quantification of brominated diphenyl ethers from all samples was performed by pressurised liquid extraction with DCM and 2-propanol (100 bar, 100°C, 3 cycles) followed by a dilution and filtration step.

PBDEs by GC-High resolution MS

Each sample was spiked with each 10 µL of the internal standards MBDE-MXG and MBDE-ISS-G. After thoroughly mixing the sample was subjected to GC-HRMS analysis.

The GC-HRMS (Thermo MAT 95 S) was operated in single ion monitoring mode (SIM), monitoring two fragment ions per analyte. PBDEs were quantified by an internal standard method.

The applied methods are in accordance with IEC 62321. The GC separation parameters are provided Table D.2and measurement criteria for the PBDEs in Table D.3

Table D.2 GC parameters

Parameter	Conditions
Injection temperature	300 °C
Injection method	splitless (1 min)
Injection volume	1 µl
Carrier gas	Helium
Column flow	1,2 ml/min (constant flow)
Oven temperature	170 °C (2.5 min) 20 °C/min-230 °C (4 min) 20 °C/min-340 °C (4 min)
Column	pre column (deactivated, 2m x 0.32 mm)+ DB-5HT (15 m x 0.25 mm, 0.1 µm) (Agilent J&W)

Table D.3 GC-HRMS PBDE ion masses

	Native	Internal Standard	Lock/Cali Mass
TriBDE	405.8026	407.8006	392.9751 l
	417.8429	419.8409	430.9723 c
TetraBDE	483.7126	495.7529	480.9688 l
	485.7106	497.7508	504.9691 c
PentaBDE	563.6211	575.6614	554.9644 l
	565.6191	577.6593	580.9627 c
HexaBDE	481.6970	493.7372	480.9688 l
	483.6950	495.7352	504.9691 c
HeptaBDE	561.6055	573.6457	554.9644 l
	563.6035	575.6437	592.9627 c
OctaBDE	639.5160	651.5562	630.9585 l
	641.5140	653.5542	654.9595 c
NonaBDE	719.4245	731.4647	704.9531 l
	721.4225	733.4626	754.9531 c
DecaBDE	797.3350	809.3752	792.9497 l
	799.3329	811.3732	830.9467 c

HBCDD

The initial extraction solvent of the filtrated extract was evaporated under a gentle stream of nitrogen. The residue was dissolved in 50% ethanol, filtered using a 0.22 µm PTFE membrane filter and analysed via LC-MS.

The quantitative determination of HBCDD took place through measurement of aliquots of the extracts via HPLC-MS after a solvent change to EtOH/water. The ionization method was electrospray (ESI) in a heated gas flow (HESI2-source).

For identification and quantification, a LC tandem mass spectrometer (Thermo TSQ Quantum Ultra AM) was used in MRM Mode using substance-specific mass transitions. The quantification was based on external calibration standards. The transitions are provided in Table D.4.

Table D.4 MRM transitions for HBCDD

Substance	CAS Nr.	Parent ION (m/z)	Daughter ION (m/z)
α-HBCDD	134237-50-6	640.6	78.8 + 80.8*
β-HBCDD	134237-51-7	640.6	78.8 + 80.8*
γ-HBCDD	134237-52-8	640.6	78.8 + 80.8*

***Quantitative mass transition**

D2.2.4 Method description for further validation measurements

As previously discussed, the adopted quality control procedures identified a number of discrepancies between the PBDE and HBCDD concentrations determined using standard methodologies and the XRF data. Therefore, further work was undertaken to improve the accuracy of the data and the reporting of the compounds, specifically decaBDE.

Static toluene extraction (decaBDE)

To investigate potential solubility issues a second set of samples was extracted using a a less polar toluene solvent.

The sample material was weighed into 50 mL centrifuge tubes together with 10 mL toluene (distilled quality). The extraction was carried out for 15 h on an orbital shaker (175 rpm). After centrifugation for 10 min at 15000 rpm an aliquot of 1 mL of the supernatant was taken out and transferred into a 10 mL volumetric flask. The flask was filled beforehand with approximately 8 mL n-hexane (pesticide grade) to which the toluene extract was added dropwise to promote the precipitation of dissolved polymers. The flask was then filled completely with n-hexane to the mark. The whole toluene/n-hexane mixture was then filtered through syringe filters (PTFE membrane, 0.45 µm). An aliquot of the filtrated extract was then taken for HBCDD analysis via LC-MS (Thermo TSQ Quantum LC-MS-MS, neg mode, ESI, SRM; Column: EVO C18). An aliquot of the extract was analyzed by GC-ECD and (for three samples) by GC-Quadrupole-MS.

Screening of samples with GC-quadrupole MS

A screening for unknown compounds for a subset of three samples was performed on a gas chromatography (quadrupole) mass spectrometry system of the type Shimadzu QP2010 Ultra for validation purposes. An additional aim of this work was to verify that there was no loss of DecaBDE on the analytical columns.

The used GC-MS-method was based on a simplified GC-MS-method for brominated flame retardants proposed by the National Institute for Environmental Studies, Japan (Table D.5).

Table D.5 GC-MS screening parameters

Method	Parameter	Conditions
GC	Injection temperature	300 °C
	Injection method	splitless (1 min)
	Injection volume	0.5 µl
	Carrier gas	Helium
	Column flow	2.65 ml/min (constant flow)
	Oven temperature	100 °C (1 min) 65 °C/min-175 °C (0 min) 45 °C/min-300 °C (0 min) 35 °C/min-320 °C (0.5 min)
	Column	DB-5HT (5 m x 0.25 mm, 0.1 µm) (Agilent J&W)
MS	Interface temperature	300 °C
	Ion source temperature	230 °C
	Ionisation energy	70 eV
	Full scan mass range	150 – 850 m/z

Static extraction of a further subset of samples

A further subset of samples were extracted by means of a static toluene extraction. An amount of 0.5 g of sample was mixed with 50 ml toluene (distilled quality) and stored at 60°C for a period > 10 hours. The samples were directly analyzed by GC-ECD for TBBPA. After solvent exchange the extract was analyzed on HPLC-MS for phosphor-based flame retardants.

GC-ECD

The GC-ECD was used for a screening for TBBPA and a look for further halogenated substances. Set-up conditions are provided in Table D.6.

Table D.6 GC parameters for GC-ECD measurement

Parameter	Conditions
Injection temperature	300 °C
Injection method	splitless (1 min)
Injection volume	1 µL
Carrier gas	Helium
Column flow	1,2 mL/min (constant flow)
Oven temperature	170 °C (2.5 min) 20 °C/min-230 °C (4 min) 20 °C/min-340 °C (4 min)
Column	pre column (deactivated, 2m x 0.32 mm)+ DB-5HT (15 m x 0.25 mm, 0.1 µm) (Agilent J&W)

Phosphor-based flame retardants

After filtration, an aliquot of 1 mL was evaporated under a gentle nitrogen stream. The residue was dissolved in 1 mL acetonitrile (LCMS grade), filtered (0.22 µm Nylon) and analyzed by LC-MS/MS. The quantification was based on external calibration standards.

For identification and quantification, a LC tandem mass spectrometer (Waters Quattro Ultimate Platinum) was used in MRM Mode using substance-specific mass transitions (Table D.7). Ionization was performed by heated electrospray ionization (HESI) in positive mode. For each substance two MRM-transitions have been measured and quantified. There was only one MRM-transition for the substance Diphenyl (ethylhexyl) phosphate. MRM transitions are identified in Table D.7.

Table D.7 MRM transitions for organophosphorous flame retardants

Substance	CAS Nr.	Parent ION (m/z)	Daughter ION1 (m/z)	Daughter ION2 (m/z)
Tri(iso)butyl phosphate	126-71-6	267.1	99.1	155.1
Tris(2-chlorethyl) phosphate	115-96-8	284.9	99.1	222.9
Triphenyl phosphate	115-86-6	326.9	77.3	152.1
Tris(2-chlorpropyl) phosphate (Mixture of isomers)	13674-84-5	326.9	99.1	250.9
Diphenyl(ethylhexyl) phosphate	1241-94-7	363.0	251.0	-
Tris(2-butoxyethyl) phosphate	78-51-3	399.1	101.3	299.1
Tris(2-ethylhexyl) phosphate	78-42-2	435.0	99.1	210.9

D2.2.5 Summary of approach and findings

The bromine content based on XRF could not be explained by the amounts of brominated compounds (PBDEs and HBCDD) found by means of LC-MS and GC-MS therefore a search for other flame retardants and bromine sources was performed.

Two main interfering factors were identified:

- Phosphor based flame retardants which cause solubility issues when present especially with the samples extracted with ASE.
- BDPE 209 (decabromodiphenylethane) was identified as a main source of bromine in some samples.

The results presented in this report include the results from GC-HMRS for the PBDEs and the HBCDD results are from HPLC-MS. DecaBDE (BDE-209) and NonaBDE (BDE-207) concentrations were validated using GC-ECD and are based on a static toluene extraction. During this extraction no solubility limitations or interfering influences were observed. The HBCDD data were also validated using the toluene extraction and EC-ECD measurement.

GC-quadrupole-MS screenings revealed the presence of BDPE 209 in a number of samples. BDPE 209 was only present in the toluene extracts and not in the ASE extracts which might be explained by the less polar nature of the compound. Decabromodiphenyl ethane (BDPE 209) is used as a replacement flame retardant for the structurally similar decabromodiphenyl ether (decaBDE). Quantitative analytical testing did not detect TBBPA.

D3 Tier 2 Screening Results

The results of the Tier 2 screening analysis are provided in Table D.8. The results have been generated from a qualitative analysis technique and therefore provided as concentration ranges. The PBDE and decaBDE data will be provided once analytical test data has been refined as the current extraction efficiency has not been satisfactorily proven.

The results are presented for the following compounds:

- Chlorinated phosphorous flame retardants (Cl-PFRs)
    i. Tris(2-chloroethyl) phosphate (TCEP)
    ii. Tris(2-chloroisopropyl) phosphate (TClPP)
- Brominated flame retardants (BFRs)
    i. Decabromodiphenylethane (DBDPE)
    ii. Hexabromocyclododecane (HBCDD)
    iii. Ethylene bis(tetrabromophthalimide) (EBTBP)
    iv. Tetrabromobisphenol A (TBBPA)
- Chlorinated paraffins (CPs)
    i. Short chain chlorinated paraffins (SCCPs)
    ii. Medium chain chlorinated paraffins (MCCPs).

Table D.8 Results of the Tier 2 qualitative analysis

	Cl-PFRs			Br-PFRs		BFRs						CPs	
Sample ID	TCEP 115-96-8	TCIPP 13674-84-5	TDCIPP 13674-87-8	TBPP 126-72-7	TNBPP 19186-97-1	PBDEs	BDE209 1163-19-5	DBDPE 284-366-9	HBCDD 3194-55-6	EBTBP 32588-76-4	TBBPA 79-94-7	SCCPs 85535-84-8	MCCPs 85535-85-9
KM22-A	-	X	-	-	-	-	**XX** 7.5%*	-	-	-	-	-	XX
KM16-A	-	X	X	-	-	-	**X** 0.18%*	-	-	-	-	-	-
WF24-A	-	-	-	-	-	-	**X** 0.16%*	-	-	-	-	-	-
HH56-A	-	-	-	-	-	-	(x) 0.0%*	-	X	-	-	-	-
WF16-A	-	(x)	-	-	-	-	(x) 0.02%*	-	-	-	-	-	X
CC17-A	-	(x)	-	-	-	-	**X** 0.09%*	-	XX	-	-	-	-
CC4-B	X	-	-	-	-	-	**XX** 4.4%*	-	-	-	-	-	-
CC11-B	-	(x)	-	-	-	-	(x) 0.0%*	-	-	-	-	-	-
CC27-B	-	-	-	-	-	-	**XX** 9.8%*	-	-	-	-	-	XX
WF2-A	-	X	-	-	-	-	**X** 0.09%*	-	-	-	-	-	-
CC26-C	-	XX	-	-	-	-	**X** 0.12%*	-	-	-	-	-	-
WF6-B	-	XX	-	-	-	-	(x) 0.0%*	-	-	-	-	-	-
LC22-D	-	XX	-	-	-	-	**XX** 7.2%	-	-	-	-	-	-
CC17-B	-	X	-	-	-	-	**XX** 11.4%*	-	X	-	-	-	-
CC5-C	-	-	-	-	-	-	**X** 0.07%*	-	-	-	-	-	-
KM17-B	-	XX	-	-	-	-	**XX** 4.4%*	-	XX	-	-	-	-
KM17-A	-	X	-	-	-	-	**XX** 11.8%*	-	-	-	-	-	-
CC23-B	-	(x)	-	-	-	-	**XX** 13.7%*	-	-	-	-	-	-
WF21-C	-	X	-	-	-	-	**XX** 8.1%*	-	-	-	-	-	-
LC17-D	-	XX	-	-	-	-	**XX** 1.05%*	-	-	-	-	-	-

Key: XX = >1% w/w, **X** = >0.1% w/w, (x) = below <0.1% w/w, **-** = not detected. * = quantitative confirmatory analysis by Eurofins (%w/w).

Sample submitted for Tier 3 screening

D4 Tier 3 test data for HBCDD, PBDEs and Deca-BDPE

The results of the Tier 3 testing are shown in Table D.9Table D.10 and have been split into the sample categories. The highlighted cells show results which were validated with GC-ECD measurements. Table D.11 shows a simplified bromine mass balance or bromine accountability for each sample based on the XRF results before and after extraction and the bromine compounds determined through the GC measurements.

Table D.9 HBCDD, PBDE and deca-BDPE concentrations in textile and leatherette 'cover' samples

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
Textile covers											
CC17-A	Sofa	92,997	0.98	n.d. (<0.24)	n.d. (<0.92)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<40.6)	n.d. (<18.4)	696	n.d. (<10.0)
CC27-B	Sofa	45	n.d. (<0.41)	n.d. (<0.26)	1	1	8	210	1,841	114,234	n.d. (<10.0)
CC25-B	Sofa	n.d. (<10.0)	n.d. (<0.57)	n.d. (<0.39)	2	3	24	277	2,006	121,472	n.d. (<10.0)
CC11-B	Sofa	n.d. (<10.0)	n.d. (<0.57)	n.d. (<0.18)	n.d. (<0.70)	1	12	171	1,754	97,951	n.d. (<10.0)
CC8-A	Armchair	161	n.d. (<0.33)	n.d. (<0.24)	n.d. (<1.08)	1	21	204	1,498	82,889	n.d. (<10.0)
CC23-B	Armchair	414	n.d. (<0.38)	n.d. (<0.20)	n.d. (<1.42)	n.d. (<0.51)	6	140	1,180	75,195	n.d. (<10.0
CC4-B	Armchair	n.d. (<10.0)	n.d. (<0.5)	0.4	1	1	4	207	1,666	71,890	n.d. (<10.0)
CC6-A	Dining chair	n.d. (<10.0)	n.d. (<0.5)	0.4	1	1	7	205	2,330	93,198	n.d. (<10.0)
WF16-B	Sofa	n.d. (<10.0)	n.d. (<0.59)	0.5	1	1	5	238	1,942	98,857	5,229
WF24-A	Armchair	n.d. (<10.0)	n.d. (<0.28)	0.3	1	2	15	273	2,174	118,050	n.d. (<10.0)

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
WF9-A	Footstool	n.d. (<10.0)	n.d. (<0.26)	n.d. (<0.17)	n.d. (<0.66)	1	12	203	1,195	65,305	77
KM22-B	Armchair	44	n.d. (<0.03)	n.d. (<0.05)	0.8	1	13	157	1,489	90,536	178
KM11-D	Footstool	2,352	0.2	0.2	3	6	41	483	165	2,285	n.d*
KM16-A	Sofa	48	n.d. (<0.03)	n.d. (<0.05)	0.1	0.6	1	11	23	217	7,387
KM17-A	Sofa	29,149	n.d. (<0.03)	n.d. (<0.05)	0.8	n.d. (<0.51)	3	126	886	43,398	11
LC15-B	Sofa	58	n.d. (<0.04)	n.d. (<0.07)	1	5	34	516	241	6,333	n.d.*
LC22-A	Sofa	8	n.d. (<0.03)	0.22	1	1	7	209	1,349	68,286	n.d. (<10.0)
LC33-G	Armchair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	1	1	8	111	1,502	97,951	n.d.
HH19-A	Sofa	119	n.d. (<0.26)	n.d. (<0.17)	n.d. (<0.57)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<0.51)	n.d. (<28.8)	2,929	7,598
HH56-A	Sofa	15,195	n.d. (<6.13)	n.d. (<0.31)	2	1	7	164	1,141	81,267	499
HH72-A	Sofa	699	n.d. (<1.70	n.d. (<0.31)	n.d. (<1.50)	1	3	319	4,325	204,245	576
Leatherette covers											
WF2-A	Dining chair	289	0.6	0.6	n.d. (<1.52)	2	12	103	426	44,257	n.d. (<10.0)
WF16-A	Sofa	18,959	n.d. (<0.35)	n.d. (<0.21)	n.d. (<1.08)	0.5	6	133	n.d. (<22.1)	n.d. (<859)	n.d.*
KM22-A	Armchair	n.d. (<10.0)	0.04	n.d. (<0.05)	0.9	1	12	185	1,969	137,212	264
LC29-A	Sofa	53	n.d. (<0.05)	n.d. (<0.05)	0.3	n.d. (<0.51)	4	62	391	45,883	11,227

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
HH2-A	Sofa	128	n.d. (<0.53)	n.d. (<0.31)	n.d. (<1.19)	n.d. (<0.51)	n.d. (<1.01)	26	16	1,548	8,142
HH22-A	Sofa	n.d. (<10.0)	n.d. (<0.46)	n.d. (<0.31)	n.d. (<0.96)	n.d. (<0.51)	n.d. (<1.01)	33	n.d. (<14.2)	n.d. (<1,023)	6,224

Table D.10 HBCDD, PBDE and Deca-BDE concentrations in foam and lining samples

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
Foams											
CC17-B	Sofa	1,027	n.d. (<0.43)	n.d. (<0.24)	n.d. (<1.53)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<21.1)	n.d. (<15.1)	28	n.d. (<10.0)
CC5-C	Sofa	562	0.3	n.d. (<0.14)	n.d. (<0.59)	n.d. (<0.51)	2	77	183	10,563	n.d. (<10.0)
CC8-H	Armchair	53	n.d. (<0.23)	n.d. (<0.14)	n.d. (<0.59)	n.d. (<0.51)	3	56	56	3,186	n.d. (<10.0)
WF16-C	Sofa	n.d. (<10.0)	n.d. (<0.42)	n.d. (<0.26)	n.d. (<0.5)	n.d. (<0.51)	n.d. (<1.01)	33	85	4,240	137
WF6-B	Office chair	16	n.d. (<0.41)	n.d. (<0.21)	n.d. (<1.00)	n.d. (<0.51)	1	37	n.d. (<27.0)	1,820	30
KM17-B	Sofa	429	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	n.d. (<1.01)	n.d. (<43.0)	n.d. (<35.0)	871	n.d. (<10.0)
KM20-C	Sofa	39	n.d. (<0.03)	n.d. (<0.05)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<18.4)	n.a. (<17.0)	385	n.d. (<10.0)

Sample code	Item source	Concentration (mg kg-1)									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
KM37-B	Sofa	148	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	3	50	72	3,099	n.d. (<10.0)
KM40-C	Sofa	9	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	1	31	23	363	3,760
KM12-E	Armchair	52	0.1	0.1	1	9	27	488	434	7,404	n.d.*
KM26-D	Armchair	25	n.d. (<0.03)	n.d. (<0.05)	0.1	0.6	1	36	45	1,099	587
LC22-D	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	0.1	n.d. (<0.51)	n.d. (<1.01)	34	28	967	338
LC26-C	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	0.1	n.d. (<0.51)	1	41	18	802	3,112
LC38-C	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.04)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<39.2)	n.d. (<16.3)	n.d. (<713)	n.d. (<100)
LC38-D	Sofa	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	n.d. (<0.03)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<36.4)	n.d. (<18.1)	74	73
LC44-D	Armchair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.06)	n.d. (<0.05)	n.d. (<0.51)	n.d. (<1.01)	n.d. (<34.1)	n.d. (<20.4)	133	1,369
HH51-D	Sofa	n.d. (<10.0)	n.d. (<6.33)	6	n.d. (<0.99)	1	11	228	19	134,311	127
HH32-C	Armchair	315	11,686	17,478	n.d. (<0.96)	n.d. (<0.51)	n.d. (<1.01)	50	n.d. (<30.3)	36	44
HH34-C	Armchair	n.d. (<10.0)	n.d. (<49.17)	n.d. (<0.31)	n.d. (<0.99)	n.d. (<0.51)	n.d. (<1.01)	14	n.d. (<18.5)	61	44
Linings											

Sample code	Item source	Concentration (mg kg^{-1})									
		HBCDD	tetraBDE BDE-47	PentaBDE BDE-99	HeptaBDE BDE-183	OctaBDE BDE-197	OctaBDE BDE-196	NonaBDE BDE-206	NonaBDE BDE-207	DecaBDE BDE-209	Deca-BDPE
CC23-D	Armchair	6,085	n.d. (<0.20)	n.d. (<0.34)	n.d. (<1.08)	1	5	122	159	12,215	n.d. (<10.0)
WF2-D	Dining chair	16	n.d. (<0.41)	n.d. (<0.22)	n.d. (<0.69)	1	7	263	52	1,739	n.d.*
LC7-D	Office chair	n.d. (<10.0)	n.d. (<0.03)	n.d. (<0.05)	0.1	5	23	531	290	5,736	n.d.*
HH19-B	Sofa	396	n.d. (<0.26)	n.d. (<0.26)	n.d. (<0.90)	n.d. (<0.51)	2	177	n.d. (<29.0)	390	n.d.*

n.d. – not detected (detection limit in brackets)

n.d.* not detected, extraction was performed with polar solvent which may have resulted in underestimated results

Table D.11 Simplified bromine mass balance

Sample number	Initial sample XRF (ppm Br)	XRF after extraction (ppm Br)	Extraction efficiency of toluene %	% bromine explained by analysis	Remarks
KM11-D	70,810	-	N/A	7%	Br content is not explained, lack of sample
KM12-E	10,307	-	N/A	64%	Br content is largely explained
KM16-A	74,797	58,410	22%	8%	Low extraction efficiency
KM17-A	48,393	216	~ 100%	~ 100%	Br content is explained
KM17-B	5,480	3,866	295	20%	Low extraction efficiency, extracted bromine is explained
KM20-C	15,053	8,076	46%	2%	Medium extraction efficiency, brominated compounds not suitable for GC assumed present
KM22-A	76,630	6	100%	~ 100%	Br content explained
KM22-B	65,957	7	100%	~ 100%	Br content explained
KM26-D	12,337	11,320	8%	8%	Low extraction efficiency, but analytical data fits well
KM37-B	14,303	6,534	54%	16%	Medium extraction efficiency, brominated compounds not suitable for GC assumed present
KM40-C	3,297	0.3	100%	~ 100%	Br content explained
LC15-B	65,707	-	N/A	8%	Lack of data
LC22-A	40,733	48	100%	~ 100%	Br content explained
LC22D	15,440	13,620	12%	9%	Low extraction efficiency, but data fits well
LC26-C	23,750	11,630	51%	12%	Br not explained
LC7-D	9,344	-	N/A	50%	Medium extraction efficiency, lack of some data
LC29-A	47,873	32,370	32%	~ 100%	Br content is explained

Sample number	Initial sample XRF (ppm Br)	XRF after extraction (ppm Br)	Extraction efficiency of toluene %	% bromine explained by analysis	Remarks
LC33-G	40,830	0.5	100%	~ 100%	Br content is explained
LC38-C	15,487	15,770	0%	0.2%	Low extraction efficiency
LC38-D	14,737	13,910	6%	0.7%	Low extraction efficiency
LC44-D	15,467	13,090	15%	7%	Low extraction efficiency, but data fits well
CC17-A	54,507	-	N/A	~ 100%	Br content explained
CC17-B	1,583	73	95%	76%	Br content explained
CC8-A	41,517	271	99%	~ 100%	Br content explained
CC23-B	7,533	1.4	100%	~ 100%	Br content explained
CC23-D	7,533	1.4	100%	~ 100%	Br content explained
CC27-B	74,813	9.5	100%	~ 100%	Br content explained
CC25-B	58,647	7.2	100%	~ 100%	Br content explained
CC4-B	35,263	7	100%	~ 100%	Br content explained
CC6-A	52,150	3.6	100%	~ 100%	Br content explained
CC11-B	48,790	1.5	100%	~ 100%	Br content explained
CC8-H	2,102	54.6	97%	~ 100%	Br content explained
CC5-C	10,517	5.8	100%	~ 100%	Br content explained
WF2-A	29,217	-	N/A	~ 100%	Br content explained
WF2-D	14,040	-	N/A	16%	Br content is generally low
WF6-B	19,997	8,287	59%	14%	Br not explained

Sample number	Initial sample XRF (ppm Br)	XRF after extraction (ppm Br)	Extraction efficiency of toluene %	% bromine explained by analysis	Remarks
WF16-A	51,423	65.7	100%	~ 100%	Br content explained
WF16-B	45,053	10.6	100%	~ 100%	Br content explained
WF16-C	1,981	5.1	100%	~ 100%	Br content explained
WF24-A	42,910	4.9	100%	~ 100%	Br content explained
WF9-A	31,647	14.1	100%	~ 100%	Br content explained
HH19-A	70,427	58,530	17%	10%	Low extraction efficiency
HH19-B	9,045	-	N/A	16%	Low extraction efficiency, lack of data
HH2-A	66,210	52,730	20%	11%	Low extraction efficiency
HH22-A	29,280	18,600	36%	17%	Low extraction efficiency
HH32-C	18,493	63.4	100%	~ 100%	Br content explained
HH34-C	22,687	39.2	100%	14%	Br not explained
HH51-D	78,643	-	N/A	0.9%	Low extraction efficiency, lack of some data
HH56-A	57,590	3,373	94%	~ 100%	Br content explained
HH72-A	104,167	24.3	100%	~ 100%	Br content explained

D5 Tier 3 Organophosphorous Flame Retardants

In addition to the HBCDD and PBDE analysis, some of the samples sent for Tier 3 testing were also tested for organo PFRs. Some samples were shown to have high concentrations of chlorinated PFRs, in-particular Tris(2-chloropropyl) phosphate which is normally present as a mixture of isomers. The compounds tested for are listed in Table D.7 and the results are presented in Table D.12.

D6 Test Data Comparison

Table D.12 Results of organophosphorous flame retardant analysis

Sample	Component	Tris(2-chlorethyl) phosphate (m/z 223)	Tris(2-chlorpropyl) phosphate (m/z 251)	Tri(iso)butyl phosphate (m/z 155)	Triphenyl phosphate (m/z 152)	Tris(2-butoxyethyl) phosphate (m/z 299)	Diphenyl(ethyl hexyl) phosphate (m/z 251)	Triphenyl phosphate (m/z 152)
KM16-A	textile cover	n.d (<0.25)	1450.4	0.1	158.7	72.	79.1	1.82
KM17-A	textile cover	n.d (<0.25)	3445.3	0.7	0.3	6.5	0.4	0.26
LC22-A	textile cover	n.d (<0.25)	261.0	0.3	0.4	17.2	0.1	0.29
LC26-C	foam	0.26	103510	0.4	8.8	3.2	49.0	0.28
LC38-C	foam	n.d (<0.25)	61688	1.2	2.4	15.7	4.0	n.d (<0.25)
CC17-A	textile cover	2.2	675.2	0.4	20.4	0.5	5.6	0.4
CC8-A	textile cover	17.5	248.0	0.3	0.5	0.2	0.1	0.5
WF2-A	Leatherette cover	6.5	2717.4	0.3	9.9	14.6	1.6	1.2
WF6-B	foam	3.5	21421	0.4	4.1	13.8	0.7	0.7
HH51-D	Foam	0.3	55.3	0.5	0.3	0.1	0.2	0.3
HH19-A	lining	0.4	87.1	0.1	49.5	0.8	0.1	0.1
HH22-A	Leatherette cover	0.4	1522.7	0.4	13.3	2.7	8.1	0.1
HH32-C	Foam	61.5	25.0	0.3	1332.	1.0	0.2	0.8
HH72-A	textile cover	1.0	572.6	0.5	2.6	4.6	3.4	0.9

Table D.13 provides a comparison between Tier 1 (XRF – hand-held), Tier 2 (Chemical screening) and Tier 3 quantitative testing (XRF – WD-XRF). Generally there is a good comparison between the different tests but some are different particularly foam polymer samples. Eurofins and Amsterdam report high DecaBDE concentrations in the foams in comparison to Fraunhofer. Interestingly the XRF data reported for some of these samples is much lower than the reported decaBDE concentration. Whilst this could be due to poor representativity in the XRF scanning the WRc XRF scanning on the whole sample and that undertaken by Fraunhofer on the finely ground sample is comparable, which points to the fact that the flame retardants are ‘reactive’ rather than ‘additive’. If the flame retardant was present as a surface coating we would expect the ground whole sample ‘front and back’ to give a lower XRF reading.

There are some textile cover samples where the XRF value is lower than the decaBDE concentration reported by all three laboratories at percentage levels. In a couple of instances, the Fraunhofer XRF is a couple of percentage points higher than the WRc value, but in these cases they report an over-recovery of bromine i.e. 120% bromine extraction or 150% in some cases. As Eurofins also report a similar decaBDE value this potentially represents the margin of error between laboratories.

The available data shows a high level of comparability and therefore we can be confident that we have shown beyond reasonable doubt that the concentration of POPs in domestic seating exceeds thresholds although the accuracy of definitive concentrations is subject to some error. The data does indicate that testing these types of matrices is extremely difficult and application of standard methods may not be sufficient. Technical expertise in this instance has been used to overcome initial extraction and precipitation issues to generate a robust dataset to support regulatory decision making.

Table D.12 Results of organophosphorous flame retardant analysis

Sample	Component	Tris(2-chlorethyl) phosphate (m/z 223)	Tris(2-chlorpropyl) phosphate (m/z 251)	Tri(iso)butyl phosphate (m/z 155)	Triphenyl phosphate (m/z 152)	Tris(2-butoxyethyl) phosphate (m/z 299)	Diphenyl(ethyl hexyl) phosphate (m/z 251)	Triphenyl phosphate (m/z 152)
KM16-A	textile cover	n.d (<0.25)	1450.4	0.1	158.7	72.	79.1	1.82
KM17-A	textile cover	n.d (<0.25)	3445.3	0.7	0.3	6.5	0.4	0.26
LC22-A	textile cover	n.d (<0.25)	261.0	0.3	0.4	17.2	0.1	0.29
LC26-C	foam	0.26	103510	0.4	8.8	3.2	49.0	0.28
LC38-C	foam	n.d (<0.25)	61688	1.2	2.4	15.7	4.0	n.d (<0.25)
CC17-A	textile cover	2.2	675.2	0.4	20.4	0.5	5.6	0.4
CC8-A	textile cover	17.5	248.0	0.3	0.5	0.2	0.1	0.5
WF2-A	Leatherette cover	6.5	2717.4	0.3	9.9	14.6	1.6	1.2
WF6-B	foam	3.5	21421	0.4	4.1	13.8	0.7	0.7
HH51-D	Foam	0.3	55.3	0.5	0.3	0.1	0.2	0.3
HH19-A	lining	0.4	87.1	0.1	49.5	0.8	0.1	0.1
HH22-A	Leatherette cover	0.4	1522.7	0.4	13.3	2.7	8.1	0.1
HH32-C	Foam	61.5	25.0	0.3	1332.	1.0	0.2	0.8
HH72-A	textile cover	1.0	572.6	0.5	2.6	4.6	3.4	0.9

Table D.13 Tier 2 and Tier 3 data comparison (3 test laboratories)

Sample		Bromine by XRF (%w/w)	BDE209 (% w/w)			HBCDD (% w/w)	
			Tier 2	Eurofins	Tier 3	Tier 2	Tier 3
CC11-B	Textile cover	4.1	<0.1	0.0	9.8		
CC17-A	Textile cover	6.7	>0.1	0.09	0.07	>1	8.0
CC17-B	Foam	0.8	>1	11.4	0.003	>0.1	0.1
CC23-B	Textile cover	3.6	>1	13.7	7.5		
CC27-B	Textile cover	3.3	>1	9.8	11.4		
CC4-B	Textile cover	5.3	>1	4.4	7.2		
CC5-C	Foam	0.6	>0.1	0.07	1.1		
HH56-A	Textile cover	8.0	<0.1	0.0	8.1	>0.1	1.5
KM16-A	Textile cover	9.6	>0.1	0.18	0.09		
KM17-B	Foam	0.5	>1	4.4	0.09	>1	0.04
KM22-A	Leatherette cover	11.5	>1	7.5	9.1		
LC22-D	Foam	1.7	>1	7.2	0.16		
WF16-A	Leatherette cover	6.8	<0.1	0.02	0.09		
WF24-A	Textile cover	8.9	>0.1	0.16	11.8		
WF2-A	Leatherette cover	2.3	>0.1	0.09	0.28		
WF6-B	Foam	1.8	<0.1	0.0	0.18		

Appendix E Brominated Flame Retardant and Brominated POPs Tonnages in Waste Domestic Seating

Based on the results of the XRF and further chemical testing, the amount of BFRs and POPs-classified BFRs per 100,000 tonnes of waste domestic seating can be estimated.

The sampling data provides a good estimation of the flows of the different types of waste domestic seating in the UK. During the site sampling campaign all available domestic seating items were tested and so this provides a good basis to use as an estimation of the proportions of sofas, armchairs etc. in the waste stream.

Table E.1 Estimated proportions of domestic seating categories in the UK waste stream

Domestic seating category	Number sampled	Average weight of items (kg)	Estimated total weight of items sampled (kg)	Estimated mass proportion of waste stream (%)
Sofas	156	70	10,920	81%
Armchairs	65	30	1,920	14%
Office chairs	17	10	170	1%
Dining chairs	24	10	250	2%
Other	15	20	300	2%

Using the data in Table E.1 and the compositional data for each of the categories combined with the XRF and Tier 3 chemical testing data, the tonnages of BFRs and POPs-classified BFRs in domestic seating can be estimated.

To determine the tonnages of the BFRs, the tonnages of each of the components for each domestic seating category were estimated using the typical or average compositional data. This was then multiplied by the average bromine concentration for each component. Assuming all the bromine was present as flame retardants, the bromine weight was converted to the weight of decaBDE based on its relative molecular mass. This value was the estimated amount of BFRs in domestic seating.

Using the Tier 3 chemical testing data, the amount of POPs-classified BFRs in the waste stream was estimated by multiplying the estimated amount of BFRs by the proportion of the samples tested for each component which were found to contain POPs over 1%. This assumes that all the bromine in those samples were POPs-classified and no other brominated compounds were present. A minimum estimation was made using the Tier 3 > 1% proportions for each of the individual components for each domestic seating category, whereas a maximum estimation was made using the maximum proportion which was determined for the components across all categories.

The results of the calculations are shown in Table E.2 and show that there are an estimated 520 tonnes of BFRs present per 100,000 tonnes of waste domestic seating. Out of those 520 tonnes, between 364 and 476 tonnes are estimated to be POPs-classified.

The table shows that the textile covers from sofas account for 87% of the estimated POPs in the waste stream and when combined with textile covers from armchairs they account for 93% of the POPs. Despite some leatherette covers being found to contain POPs, a smaller proportion of the leatherette covers were found to contain bromine than the textile covers and so they account for only about 4% of the estimated POPs presence in the waste stream. The typically low bromine contents found in leather covers means that leather covers are not thought to contribute to the total POPs content in the domestic seating waste stream.

Table E.2 Estimated tonnes of POPs classified brominated flame retardants per 100,000 tonnes of waste domestic seating (WDS)

Domestic seating category	Estimated tonnes of component per 100,000 tonnes of WDS	Average bromine concentration determined by XRF (g/tonne)	Estimated tonnes of BFRs per 100,000 tonnes of WDS	% estimated as POPs	Estimated tonnes of POPs-classified BFRs per 100,000 tonnes of WDS (minimum)	Estimated tonnes of POPs-classified BFRs per 100,000 tonnes of WDS (maximum)
Sofas						
Textile covers	10,064	32,672	395	81%	320	395
Leatherette covers	2,681	12,665	41	25%	10	41
Leather covers	3,063	774	3	0%	0	0
Wadding	1,611	354	0.7	17%	0.1	0.2
Foam	20,133	2,028	49	17%	8	12
Lining	644	1,591	1	0%	0	0.6
Armchairs						
Textile covers	621	28,388	21	100%	21	21
Leatherette covers	177	8,845	2	100%	2	2
Leather covers	427	58	0.03	0%	0	0
Wadding	283	86	0.03	25%	0.01	0.01
Foam	1,558	1,404	3	25%	0.7	0.7
Lining	57	856	0.1	50%	0.03	0.03
Office chairs						
Textile covers	23	135	0	0%	0	0
Leatherette covers	21	452	0.01	0%	0	0.01
Leather covers	4	36	0	0%	0	0
Wadding	3	7	0	0%	0	0
Foam	38	1,239	0.1	0%	0	0.01
Lining	4	2,083	0.01	0%	0	0

Domestic seating category	Estimated tonnes of component per 100,000 tonnes of WDS	Average bromine concentration determined by XRF (g/tonne)	Estimated tonnes of BFRs per 100,000 tonnes of WDS	% estimated as POPs	Estimated tonnes of POPs-classified BFRs per 100,000 tonnes of WDS (minimum)	Estimated tonnes of POPs-classified BFRs per 100,000 tonnes of WDS (maximum)
Dining chairs						
Textile covers	62	12,351	0.9	100%	0.9	0.9
Leatherette covers	54	2,364	0.2	100%	0.2	0.2
Leather covers	33	289	0.01	0%	0	0
Wadding	18	183	0	0%	0	0
Foam	74	1,255	0.1	0%	0	0.03
Lining	7	494	0	0%	0	0
Others						
Textile covers	113	15,815	2	50%	1	2
Leatherette covers	20	19	0	0%	0	0
Leather covers	12	0	0	0%	0	0
Wadding	44	107	0	0%	0	0
Foam	553	436	0.3	0%	0	0.1
Lining	18	270	0	0%	0	0
Total			**520**		**364**	**476**