POPs and Hazardous Substances in C&D waste

Persistent organic pollutants (POPS) and hazardous substances in construction and demolition (C&D) waste

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Foreword

This report was produced by Richard McKinlay, Finlay Nelson and Jane Turrell on behalf of the Water Research Centre Limited (WRc). The project was carried out with significant contribution from other WRc team members including Graham Mustard, Stewart Davies, Claudia Peppicelli, Vivien Lim and Michael Morris.

WRc provides research and consultancy in water, waste and the environment in the United Kingdom, working with both public and private sector organisations. Amongst other activities, WRc supports the waste industry through the analysis of challenging waste streams, including waste electrical and electronic equipment, incinerator bottom ash and metal shredder residues.

WRc was commissioned to undertake this sampling and analysis programme by the Environment Agency (EA) to investigate the presence of substances classified as persistent organic pollutants (POPs) or with hazard statement codes in construction and demolition (C&D) waste, on a product category basis.

WRc personnel collected and processed over a thousand individual samples of products such as insulation, windows and doors and expanding filler from a range sites between the 29th of November 2023 and the 22nd of August 2024. Analysis and reporting were concluded in March 2025.

This report can be used by government, regulators, manufacturers, retailers, waste management companies and recyclers to understand which classified substances may be present in specific C&D products. It will help inform decision making on waste classification and management.

WRc would like to give special thanks to the waste management companies who provided access to sites and facilitated sampling, and the expert laboratories who conducted a comprehensive suite of analyses.

Executive summary

WRc was commissioned by the Environment Agency (EA) to undertake a research project to identify and quantify the presence of persistent organic pollutants (POPs) and substances classified with hazard statement codes (henceforth, 'classified substances', unless specified) in construction and demolition (C&D) waste.

The specific objectives of the project were to:

1. Obtain samples of C&D waste from a minimum of 1,000 different products which could contain classified substances.

2. Categorise, log and scan all samples using x-ray fluorescence (XRF) to provide a semi-quantitative assessment of key elements present in the products (e.g. bromine, antimony and lead) which are indicators of many target substances.

3. Carry out targeted chemical screening for classified substances based on XRF scanning on 200 samples.

4. Carry out quantitative analysis on a limited number of samples selected using chemical screening data.

5. Present and discuss the data on a product category basis to highlight any classified substances present in the products, at which levels and how this impacts a POPs or hazardous property (HP) assessment.

Table 1 shows the substances of interest in the project, and the products they were suspected to be present in.

Sampling was undertaken to collect a total of 1032 samples from target waste streams. The samples covered a range of individual products from construction and demolition waste, collected between November 2023 and August 2024 from multiple waste processing, demolition and building refurbishment sites across England. Several new products were also purchased new from online retailers. The samples were categorised based on product type into 14 categories, outlined in Table 2 (ordered by sample prevalence or priority).

Table 1 Classified substances likely to be in the C&D waste stream

Substance	Likely sources in C&D waste stream
Chlorinated paraffins (CPs) including short chained chlorinated paraffins (SCCPs) and medium chained chlorinated paraffins (MCCPs)	• Insulation • Plastics • Cables • Paints • Adhesives and sealants • Rubber products
Polychlorinated biphenyls (PCBs)	• PVC polymer • Adhesives and sealants • Textiles (carpets) • Polyurethane foam • Paints and coatings • Cables
Per- and polyfluoroalkyl substances (PFAS), including perfluorooctane sulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS) and perfluorooctanoic acid (PFOA)	• Plastics • Treated wood • Treated glass • Adhesives and sealants • Cables • Paints • Metal (as additive in metal plating
Brominated flame retardants (BFRs), including Polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD)	• Insulation • Plastics • Cables • Treated wood • Treated glass • Paints • Adhesives and sealants • Rubber products • Textiles
Dechlorane plus (DCP)	• Insulation • Plastics • Cables • Paints • Adhesives and sealants • Rubber products
UV-328	• Doors and windows • Cladding and wall coverings
Organophosphate flame retardants (OPFRs)	• Insulation • Rigid plastics
Phthalates	• Flexible PVC • Rubber products • Cables
Lead compounds	• UPVC doors and window frames • Cables
Zinc Oxide	• Rubber products • Ceramics
Antimony trioxide	• Insulation • Plastics • Cables

Table 2 Sample categories

C&D waste product category (Category)	Description
Insulation	Including insulation boards, foams, fibre glass etc.
Plastics	Plastics which are not included within other categories in this table.
Pipes and ducting	Indoor and outdoor piping including plumbing pipes, cable conduits, ducting, drain-pipes, guttering etc.
Flooring	Sampling was specifically limited to carpet tiles, underlay, linoleum, vinyl/laminated flooring etc. Single layer carpets were a low priority and were excluded from further analysis (targeted in a previous project funded by Natural Resource Wales).
Doors and window frames	UPVC doors and window frames and some associated fixtures (i.e. door seals and draft excluders).
Adhesives and sealants	Adhesives/sealants predominantly from tube based dispensing systems and removed from items such as tiles and wood.
Cladding and wall panels	External and internal panels as well as cladding and façades. Plaster/mineral boards were a low priority and excluded from further analysis.
Rubber products	Rubber products, including rubber window gaskets, piping gaskets and rubber mats.
Fixtures and fittings	Items from demolition soft strip, such as wall mounted electronics (e.g. hand dryers and air conditioning units), electrical sockets, switches etc.
Discarded construction materials	Buckets, barriers, temporary floor covers, empty product containers, etc.
Expanding filler	Expanding foams for cavity sealing, were given high priority due to current use of chlorinated paraffins in manufacture however collection was limited by low availability and volume used.
Roofing	Membrane barrier layers, plastic materials etc. Single layer plaster and tiles were excluded.
Wood (low priority)	Wood, including painted wood and composite wood. Only a small number of samples were taken during site visits, but these were not included in screening or quantitative analysis due to overlapping and concurrent work on this waste stream.
Other materials (low priority)	For example, bricks, minerals, metals and WEEE items. A small number of samples were collected for completeness but were not included in further sampling and analysis following discussions between WRc and the Environment Agency.

XRF Scanning

X-ray fluorescence (XRF) scanning was used to provide a semi-quantitative analysis of key elements present in each sample which may indicate the presence of classified substances such as POPs, arsenic trioxide, antimony trioxide, zinc oxide and lead compounds. XRF is a semi-quantitative, surface analysis method and so data is indicative and cannot be used to conclusively classify samples. It is necessary to use “worst case” compounds if only elemental data is available. This is where the entire concentration must be attributed to a substance that has the most stringent hazard statement codes which is likely to be present in the waste or product.

In the doors and window frames category 67% of samples contained lead at concentrations above hazardous property (HP) thresholds. Lead has historically been used as a stabiliser in polyvinyl chloride (PVC) formulation. Six samples in this category also contained arsenic at concentrations above HP thresholds for arsenic trioxide (an assumed worst-case compound). Lead was also particularly prevalent in pipes and ducting, and cladding and wall panels.

XRF scanning also detected zinc at concentrations exceeding the HP threshold for the hazard statement codes assigned to zinc oxide in 23% of rubber samples. Zinc oxide is used as an additive to aid the vulcanisation process in rubber products.

Semi-quantitative Screening

The XRF scanning data was used to inform the selection of 200 samples for chemical screening. The chemical screening suite included brominated flame retardants (BFRs), chlorinated paraffins (CPs), phthalates and organophosphate flame retardants (OPFRs). These groups all contain substances known to have been used in the manufacture of construction products, with some classified as POPs or with hazard statement codes. Following chemical screening, samples were selected for quantitative analysis to determine the concentration of relevant substances. Table 1.3 summarises the results obtained from XRF and quantitative analysis.

Quantitative Analysis - POPs

For all samples quantitatively analysed 11 were found to contain polybrominated diphenyl ethers (PBDEs) over the 500 mg/kg POPs threshold. Of these samples, seven were insulation products. One sample was found to contain short chained chlorinated paraffins (SCCPs) over the current 10,000 mg/kg threshold (a sample of expanding filler). Hexabromocyclododecane (HBCD) was detected in a sample of insulation at a concentration over 700 mg/kg, but due to difficulties in quantification it cannot be concluded if this is above or below the current 1,000 mg/kg POPs threshold. No other POPs included in the study were found at concentrations over the limit of quantification (LOQ).

Medium chained chlorinated paraffins (MCCPs) were detected in 20 samples at concentration exceeding 10,000 mg/kg, predominantly in the insulation, adhesives and

sealants and expanding fillers categories. The proposed listing of MCCPs under the Stockholm Convention was agreed at the POPs Review Committee in October 2024. The proposal will be discussed at the 12th meeting of the Conference of the Parties to the Stockholm Convention (CoP) scheduled for 28 April to 9 May 2025. If the listing is agreed by the CoP, Parties to the Convention will have 18 months to implement the decision in their domestic legislation.

Quantitative Analysis – Classified Substances

Brominated flame retardants (BFRs), classified or otherwise, were not quantified at the levels expected considering the concentrations of bromine and antimony detected during XRF scanning. From the quantitative analysis of 60 samples, seven were found to contain classified BFRs (primarily tetrabromobisphenol A (TBBPA)) in concentrations exceeding above the associated HP thresholds for the associated hazard statement codes.

Organophosphate flame retardants (OPFRs) with hazard statement codes tended to be present in insulation, fixtures and fittings and expanding fillers. Quantitative analysis of 20 samples found that 15 contained classified OPFRs in concentrations over the associated HP threshold. All exceedances were linked to Tris (1-chloro-2-propyl) phosphate (TCPP), Triphenyl phosphate (TPP) and tricresyl phosphate (TCP) concentrations. If present, these substances were typically at concentrations of 10,000 mg/kg or more.

Plasticisers, some of which are phthalates classified with hazard statement codes, have been used extensively in the manufacture of construction products. Despite this, only 11 samples of the 67 submitted for quantitative analysis were found to contain classified phthalates at concentrations exceeding their associated hazard statement code HP thresholds. Of these, three were flooring and three were adhesives and sealants.

Table 3 provides a summary of the number of samples found to contain a substance classified with a hazard statement code above the relevant hazardous property threshold. This study provides a baseline of data for the concentration of key classified substances in different products found within construction and demolition waste. Several challenges were encountered in quantifying target substances, principally due to the high concentrations of non-target chemicals in complex matrices, which can cause interferences and potentially overwhelm sensitive analytical instrumentation. The analysis, and therefore conclusive classification, of waste remains a challenge. Further targeted analysis of individual products may assist those who regulate or manage this waste in reaching further conclusions.

Table 3 Number of samples identified as containing classified substances above relevant thresholds

Category	Collected (n)	Number of samples with concentrations of classified substances above hazardous property thresholds based on quantitative analysis (n)				Number of samples with concentrations of worst-case compounds above hazardous property thresholds based on XRF scanning (n)			
		BFRs	CPs	Phthalate	OPFRs	Arsenic trioxide	Antimony trioxide	Zinc oxide	Lead compounds
Total	1032	7 (60)	27 (62)	11 (67)	15 (20)	15	19	42	122
Insulation	188	0 (24)	6 (12)	-	2 (5)	0	3	10	1
Plastics	150	3 (5)	1 (4)	0 (3)	0 (1)	5	3	2	19
Pipes and ducting	118	1 (3)	1 (2)	1 (6)	-	2	1	0	24
Flooring	85	-	2 (4)	3 (9)	-	0	0	7	0
Doors and window frames	78	-	1 (6)	2 (22)	-	6	2	1	52
Adhesives and sealants	66	-	4 (9)	3 (9)	-	1	0	0	2
Cladding and wall panels	66	-	2 (4)	1 (5)	1 (1)	1	2	4	13
Rubber products	62	-	1 (6)	1 (6)	-	0	2	15	1
Fixtures and fittings	57	2 (16)	0 (4)	0 (1)	7 (8)	0	6	1	3
Discarded construction materials	45	1 (4)	2 (2)	0 (2)	-	0	0	0	3
Expanding fillers	31	0 (8)	7 (9)	0 (3)	5 (5)	0	0	0	0
Roofing	18	-	-	0 (1)	-	0	0	0	0
Wood	55	-	-	-	-	-	-	1	4
Other	13	-	-	-	-	-	-	1	0

1. Introduction

1.1. Background

WRc has been commissioned by the Environment Agency (EA) to undertake a research project to identify and quantify the presence of persistent organic pollutants (POPs) in construction and demolition (C&D) waste arisings.

The UK is a signatory to the United Nations Stockholm Convention for Persistent Organic Pollutants. This controls and restricts the use of POPs and requires destruction of waste containing POPs at or above low POP concentration limits. Defra's 2018 'Waste and Resources Strategy' sets out how the UK will move to a circular economy by minimising waste and promoting resource efficiency. The UK Government's 25 Year Environment Plan enshrines these commitments whilst managing exposure to chemicals, including:

- substantially increasing the amount of POPs material being destroyed or irreversibly transformed by 2030; and
- fulfilling the UK's commitments under the Stockholm Convention[1].

This project aligns with these two key pillars of the UK's environmental ambitions by substantially improving the data available on the composition of C&D waste arisings in the UK.

The project has generated evidence on the presence of POPs in UK C&D waste arisings and will assist future management of these streams in an environmentally appropriate manner. This information can be used to inform future policy and regulation development in the UK and will contribute to the international evidence base, including that used by the United Nations such as the Stockholm and Basel Conventions.

1.2. Aims

The specific objectives of the project were to:

1. Obtain samples of C&D waste from 1,000 different products which may contain POPs, substances proposed for listing under the Stockholm Convention or other classified substances.
2. Categorise, log and scan all 1,000 samples using x-ray fluorescence (XRF) to provide a semi-quantitative assessment of key elements present in the products (e.g. bromine, antimony and lead).

[1] The Stockholm Convention on Persistent Organic Pollutants (https://www.pops.int/)

3. Carry out targeted quantitative analysis for POPs, substances proposed for listing under the Stockholm Convention (MCCPs) and a range of classified substances classified with hazard statement codes (henceforth, ‘classified substances’, unless specified) based on XRF scanning and targeted chemical screening.

4. Present and discuss the data on a product category basis to highlight any POPs or classified substances present in the products, at which levels and how this impacts a POPs or HP assessment.

1.3. Report Structure and Supplementary Dataset

Section 2 of this report provides key contextual information on C&D waste which informed the testing programme approach. Section 3 provides details on the approach, methodology and analytical methods applied. Section 4 presents the XRF scanning, targeted chemical screening and targeted quantitative analysis data for each product category. Each chapter in Section 4 is written such that it can be read in isolation. Section 5 provides a discussion on results from all categories, and Section 6 provides a critical evaluation of the data and limitations of the study.

The details of all samples collected as part of this program, as well as the results of all testing is provided as a supplementary excel dataset to this report. This is available from the EA chemicals team (enquiries@environment-agency.gov.uk).

2. Background to C&D Waste

2.1. C&D Waste Composition

C&D waste is the single largest waste stream arising in the UK annually. According to the latest published statistics on waste arisings by Defra, the UK produced over 59 million tonnes of C&D waste (excluding excavated soils and dredgings) during 2020. A total of 55 million tonnes of C&D waste was recovered (92%) and around 4 million tonnes was landfilled[2]. Table 2.1 shows the contributions of different material types to the total C&D waste arising (when minerals (i.e. concrete, bricks, ceramic and rubble), soils and dredgings are excluded, based on Defra statistics, 2018).

Table 2.1 Proportions by weight of materials in C&D waste (excluding minerals, soils and dredgings), Defra 2018

Waste type	Proportion of C&D waste
Ferrous metal	39.7%
Non-ferrous metal	15.6%
Mixed metal	19.1%
Wood	19.5%
Glass	4.2%
Plastics	2.0%

A report published by Qflow[3] investigated over 90,000 waste collection tickets between 2018 and 2023 and their analysis included a breakdown of waste categories by project type. The Qflow report data has been summarised in Table 2.2.

This analysis shows there are significant differences in waste composition based on project type. For instance, 'fit out' projects (typically referring to interior commercial construction and associated activities) had a significantly higher proportion of mixed construction and demolition waste when compared to commercial and residential projects. It should be noted however, that skips containing construction and demolition waste, particularly from smaller projects, often include a wide variety of waste types which present significant challenges to segregation and correct classification (i.e. discrete categories such as wood and plastic).

[2] Official Statistics - UK statistics on waste. Defra. Updated 28 June 2023. Available at: https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste#recovery-rate-from-non-hazardous-construction-and-demolition-cd-waste

[3] The UK Construction Industry – Annual Waste Report 2023. Qflow. Available at: https://qualisflow.com/uk-construction-waste-report-2023/ The UK Construction Industry – Annual Waste Report 2023. Qflow.

Table 2.2 Waste types based on project type (data from Qflow report, 2023)

Waste type	Proportion of C&D waste by project type			
	Infrastructure	Fit out	Residential	Commercial
Concrete	2.3%	9.5%	8.6%	32.5%
Soils	96.6%	17.8%	65.0%	34.7%
Other	1.1%	1.7%	0.2%	1.5%
Metals	-	2.7%	-	12.5%
Wood	-	5.7%	1.1%	-
Plasterboard	-	8.3%	1.2%	1.6%
Mixed plastics	-	1.0%	-	-
Mixed C&D	-	43.5%	23.9%	7.1%

The C&D waste stream is complex in terms of the number of sub-populations of differing waste streams or categories and the number of different sources of those materials within each stream. Previous studies of POPs in C&D waste include a desk-study undertaken on behalf of the EA in 2023[4] by WSP and the Wood Recyclers Association (WRA – reference not available as not in the public domain). Those investigations identified several potentially classified substances and POPs-containing materials within C&D waste streams. WSP identified 35 potentially POPs-containing materials streams arising in C&D wastes.

WRA's testing has identified several types of waste wood which are hazardous (including telegraph poles, CCA (copper chrome arsenate)/creosote-treated wood, railway sleepers, wood from engineering, ships, or vehicle applications). A further seven types of waste wood were identified as potentially hazardous, including many frequently found in C&D wastes such as: tiling, cladding and battens; barge boards, fascias and soffits; external joinery, timber frames and joists, external doors and roof timbers. Due to the quantity of existing data available for wood, this was not a priority category in this project.

2.2. Classified Substances in C&D Waste

Although the manufacture, sale and use of POPs-containing products is prohibited in the UK, due to the long service life of many construction materials, many POPs compounds may have been legitimately added at the point of manufacture to historic construction materials. These are now present in waste arising from maintenance and demolition of these buildings decades later. Additionally, the replacement chemicals for these compounds may have subsequently become substances proposed for listing under the Stockholm Convention and are still legitimately used in materials being manufactured today. Finally, due to the international trade in construction products, there is a risk that

[4] Persistent organic pollutants (POPs) in construction and demolition (C&D) waste – Desk Study for the Environment Agency, authored by WSP. Project No. 70104407. March 2023.

new products containing POPs are imported into the UK from countries that have not implemented the Stockholm Convention.

Recent analytical research carried out by WRc has shown that other materials that may be present within C&D wastes and which have been identified as containing POPs include waste electronic and electrical equipment (WEEE), soft furnishings, non-WEEE cables, carpets (and general flooring waste including carpet tiles) and polymer/rubber waste.

The EA's 2023 desk study identified several potential POPs and other substances with hazard statement codes in C&D wastes, as summarised in Table 2.3. The hazardous properties (HP) associated with these substances is given in the table, although not all substances will have all hazard statement codes for all hazard categories and thresholds may vary between substances. Note that in this project, MCCPs are defined as chloroalkanes, C14-17 (CAS number 85535-85-9). An international agreement on the definition of MCCPs is yet to be reached, and if an alternative chain length is agreed this will impact on the MCCPs concentration.

Table 2.3 Classified substances identified in C&D wastes

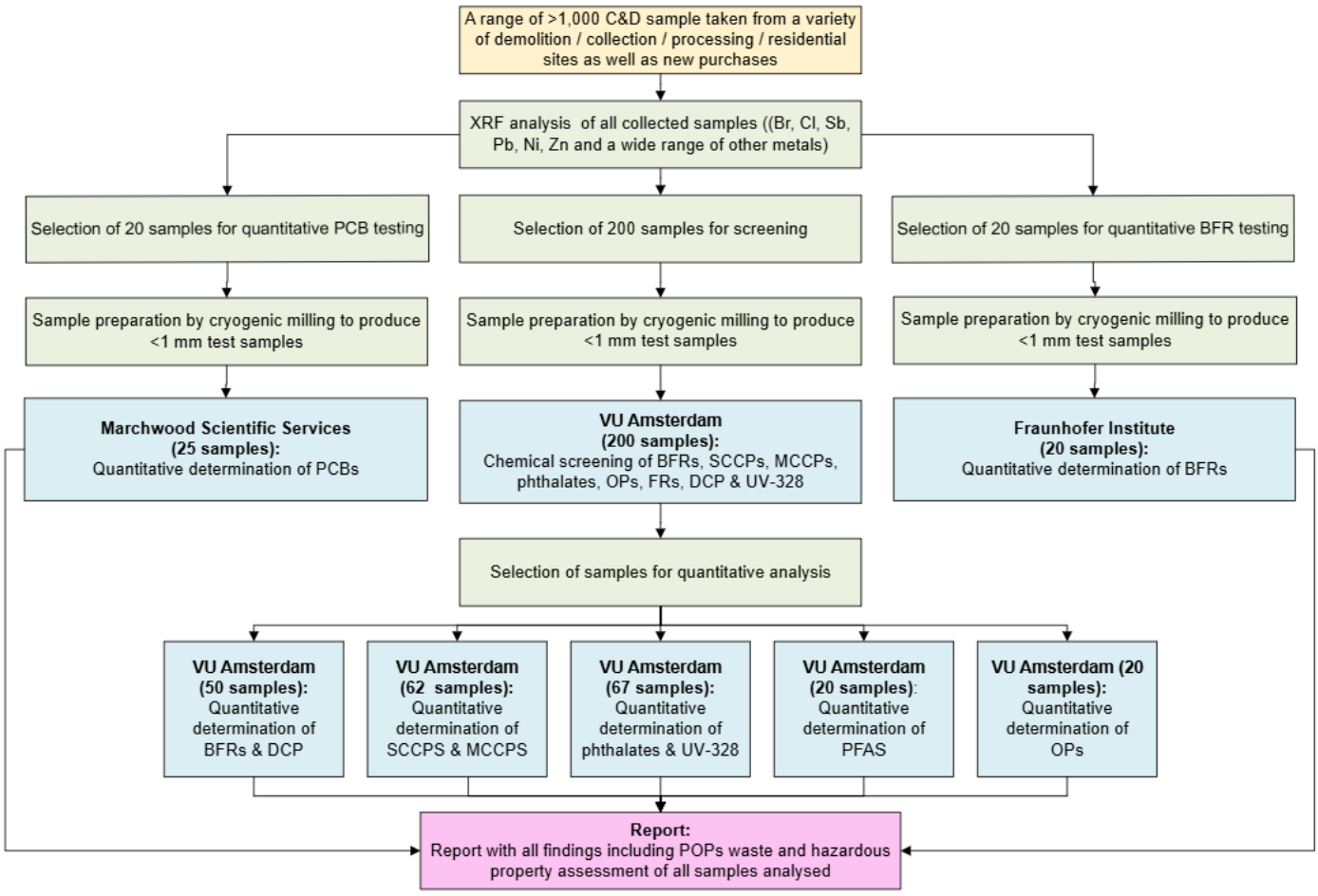
Substance	Associated classifications	Likely sources in C&D waste stream
SCCPs and MCCPs	POPs HP 7 carcinogenic HP 14 ecotoxic	• Insulation • Plastics • Cables • Paints • Adhesives and sealants • Rubber products
PCBs	POPs HP 5 specific target organ toxicity (STOT), HP 14 ecotoxic	• PVC polymer • Adhesives and sealants • Textiles (carpets) • Polyurethane foam • Paints and coatings • Cables
PFAS (including PFOS, PFHxS and PFOA)	POPs HP 4 irritant HP 5 STOT, HP 6 toxic HP 7 carcinogenic HP 10 toxic for reproduction	• Plastics • Treated wood • Treated glass • Adhesives and sealants • Cables • Paints • Metal (as additive in metal plating)
Brominated flame retardants (including PBDEs and HBCD)	POPs HP 5 STOT, HP 7 carcinogenic HP 10 toxic for reproduction HP 14 ecotoxic	• Insulation • Plastics • Cables • Treated Wood • Treated Glass • Paints • Adhesives and sealants • Rubber products • Textiles
Dechlorane Plus	POPs	• Insulation • Plastics • Cables • Paints • Adhesives and sealants • Rubber products
UV-328	POPs HP 5 STOT HP 14 ecotoxic	• Doors and windows • Cladding and wall coverings
Organophosphate flame retardants (OPFRs)	HP 6 toxic HP 7 carcinogenic HP 10 toxic for reproduction HP 14 ecotoxic	• Insulation • Rigid plastics
Phthalates	HP 10 toxic for reproduction HP 14 ecotoxic	• Flexible PVC • Rubber products • Cables
Lead compounds	HP 10 toxic for reproduction HP 14 ecotoxic	• UPVC doors and window frames • Cables

3. Approach

3.1. Testing Programme Structure

The approach adopted for this sampling and testing programme was targeted at identifying whether POPs (and classified substances as a secondary objective) may be present in C&D waste. No attempt has been made to quantify the proportion of each waste stream as a percentage of demolition waste, or mixed C&D skip waste arisings. Such an exercise would be highly complex and was beyond the scope of this project. The approach therefore aims to provide data which can identify whether POPs are present and in which C&D waste materials.

Figure 3.1 Testing programme approach



The testing programme was divided into several phases, as shown in the flow chart in Figure 3.1. Site work (yellow); testing, processing and analysis undertaken internally by WRc (green); screening and quantitative testing undertaken by subcontracted laboratories (blue); and reporting (pink). The subsequent sections provide details on the sites sampled as well as the sampling approach and sample preparation in addition to the details of the XRF scanning, chemical screening and quantitative analysis.

3.2. Sampling Methodology

3.2.1. Target C&D waste stream categories

As discussed in the previous section, C&D waste is highly complex and includes a wide range of potential sub-populations of different types of waste. Therefore, identification of target C&D waste categories was a critical first step in the design of the testing programme.

Based on the findings of an EA desk study, as well as insights gained from initial site visits by WRc as part of this testing programme, C&D priority target waste product categories (referred to as “categories” throughout the report) were identified (Table 3.1). This list was then used onsite when collecting samples to prioritise materials from different sources and reduce the collection of materials of lower interest such as wood, metals and plasterboard.

The C&D target waste categories consider materials that were available to sample on site which represented a high risk of containing POPs and other classified substances. Some potential target materials, such as cables, that may contain POPs were not included in this sampling and testing programme as previous data exists.

Additionally, materials such as paints were of interest, however, it was not possible to sample those materials directly from C&D sites as a discrete sample. Materials such as paints and flame retardants were sampled and analysed indirectly as part of other sample categories.

The target list was adjusted based on the availability and abundance of each waste stream during site visits and through real-time discussions with the EA on prioritisation of materials to be sampled. Although all samples underwent XRF scanning, some categories were given low priority for chemical screening and quantitative analysis and are therefore present in a lower frequency in the analytical dataset.

3.2.2. Sampling sites

Samples for this project were taken from nine main sources consisting of seven different waste transfer stations or active building decommissioning sites, several individual residential properties and materials purchased as new from vendors. Details of each site are provided in Table 3.2 alongside the number of samples taken at each site.

Note that soft demolition refers to the process of manually removing items from a building before demolition. The first stages include removing easily removable items such as furniture and fixtures and fittings. The latter stages of soft demolition will include the removal of flooring, pipes, ceiling tiles and insulation materials prior to major refurbishment.

Table 3.1 C&D waste target sample categories

C&D waste product category (Category)	Description
Insulation	Including insulation boards, foams, fibre glass etc.
Plastics	Plastics which are not included within other categories in this table.
Pipes and ducting	Indoor and outdoor piping including plumbing pipes, cable conduits, ducting, drainpipes, guttering etc.
Flooring	Sampling was specifically limited carpet tiles, underlay, lino, vinyl/laminated flooring etc. Single layer carpets were a low priority which were excluded from further analysis (targeted in a previous Defra project).
Doors and window frames	All doors and window frames including UPVC.
Adhesives and sealants	Adhesives/sealants predominantly from tube based dispensing systems and removed from items such as tiles and wood.
Cladding and wall panels	External and internal panels as well as cladding and façades. Plaster/ mineral boards were a low priority and excluded from further analysis.
Rubber products	Rubber products, including rubber PVC window gaskets, piping gaskets and rubber mats.
Fixtures and fittings	Items from demolition soft strip, such as wall mounted electronics (e.g. hand dryers and air conditioning units), electrical sockets and switches etc.
Discarded construction materials	Buckets, barriers, temporary floor covers, empty product containers, etc.
Expanding fillers	Expanding foams for cavity sealing, were given high priority due to current use of chlorinated paraffins in manufacture however collection was limited by low availability and volume used.
Roofing	Membrane barrier layers, plastic materials etc. Single layer plaster and tiles were excluded.
Wood (low priority)	Wood, including painted wood and composite wood. Only a small number of samples were taken during site visits, but these were not included in screening or quantitative analysis.
Other materials (low priority)	For example, bricks, minerals, metals and WEEE items. A small number of samples were collected for completeness but were not included in further sampling and analysis following discussions between WRc and the Environment Agency.

Table 3.2 Site details

Site	Type	Location	Sampling date	Material	Samples collected (n)
Site 1	C&D materials recovery facility (MRF)	Southeast England	November 2023	Mixed C&D skip waste	253
Site 2	Waste transfer station (WTS)	Southwest England	December 2023, January 2024. May 2024 and June 2024	Mixed C&D skip waste	231
Site 3	Demolition site	Southeast England	January 2024	Demolition (later stage soft demolition) removed from commercial premises	128
Site 4	Demolition site	Southeast England	February 2024	Demolition (all stages of soft demolition) removed from commercial premises	157
Site 5	Demolition site	Southeast England	April 2024	Demolition (later stage soft demolition) removed from commercial premises	77
Site 6	Household waste recycling centre (HWRC)	Northwest England (3 different sites)	August 2024	Trade and household C&D waste	18
Site 7	HWRC and WTS	Northeast England	August 2024	Trade and household C&D waste	62
Residential	Demolition site - Residential	Across UK	November 2023 to May 2024	Demolition waste removed from residential properties	89
Retail	Online retailers	Online	November 2023 to May 2024	New construction items - items manufactured in Asia targeted	17

3.2.3. Sampling approach

Sampling at each of the sites was undertaken by identification of target samples which were all labelled and photographed before being individually sealed in sample bags and transported to the WRc laboratory.

After the completion of the first sampling exercise at Site 1, sampling was predominantly limited to key target materials. Larger items, such as insulation and window frames typically required cutting equipment to generate a suitably sized sample for bagging and transport.

Sample labels consisted of unique ID number as well as a material description and these were included in each photograph to generate a digital record of the samples collected. All samples were transported to the WRc laboratory in Swindon. Logging of samples was carried out at the WRc laboratory, which included the following details:

- A unique sample identification (ID) number and sample code.
- The origin site code and site type.
- Date of sample collection.
- C&D waste material category.
- C&D waste category: this data was collected following a review of the data and is only applicable to specific categories where a wide range of material types were identified, such as insulation.
- A description of the sample.

3.2.4. Sample preparation for chemical screening and quantitative analysis

Samples selected for inclusion in the chemical screening analysis were prepared by cryogenic milling to produce a <1 mm particle size test sample. Where possible reserves of each processed sample were kept in case further analysis was required.

3.3. Sample Selection and Analytical Methodology

Analysis was carried out in three stages.

1. Initial XRF scanning to identify key elements indicative of POPs or substances classified with hazard statement codes.
2. Chemical screening of 200 targeted items to detect POPs or substances classified with hazard statement codes within concentration bands.

3. Quantitative analysis of POPs and substances classified with hazard statement codes on targeted samples based upon XRF scanning and chemical screening concentrations. Analysis was carried out with three laboratories: Vrije Universiteit Amsterdam (VU), Fraunhofer Institute and Marchwood Scientific Services (MSS).

The analytical suites were based on the classified substances which are potentially present in C&D waste. This is outlined in Section 2.2.

3.3.1. XRF scanning

XRF scanning was undertaken on every C&D sample collected using WRc's in-house Brüker S1 Titan handheld analyser with a mode specifically calibrated for polymers (Restricted Materials). Restricted materials mode utilises a number of calibrations, the most appropriate of which is automatically selected within the first few seconds of scanning based on the material under analysis including low, mid and high-density polymer material calibrations. Triplicate scans were undertaken on each sample to produce an average concentration of a range of elements including bromine, chlorine, antimony, lead and zinc.

Highly porous samples, such as foam insulation, were prepared using a 4-tonne hydraulic press to produce a compressed sample ahead of XRF analysis. The preparation was completed to try and minimise the under reporting of concentrations as a result of the materials low density. A detailed methodology can be found in Appendix A1.

A suite of target elements was identified and then extracted from the XRF results to generate a dataset for initial characterisation of the samples. The target elements were identified as indicators for the presence of POPs or substances with hazard statement codes. For example, bromine would indicate the presence of brominated flame retardants (BFRs), several of which are POPs. From this suite, key elements of the most importance have been presented in this report, with the full XRF dataset available in the accompanying spreadsheet report.

Table 3.3 shows the key elements discussed in this report and the justification for their selection.

Table 3.3 Key target elements in XRF analysis

Element	Justification
Arsenic	Arsenic has been used in polyvinyl chloride (PVC) as an additive. The exact arsenic compound present cannot be determined so a worst-case compound of arsenic trioxide has been assumed.
Antimony	Antimony trioxide is a synergist for BFRs and was used to improve the flame retardancy of PVC. If antimony and bromine are present at significant levels (>1,000 mg/kg) it suggests the bromine can be linked to the presence of BFRs.
Bromine	Bromine present in brominated flame retardants was a common additive in plastic products. Several BFRs carry hazard statement codes of relevance to hazard classification and/or are classified as POPs.
Cadmium	Cadmium as cadmium stearate has been used as a stabiliser in PVC. Cadmium sulphide has also been used as a pigment for plastics.
Chlorine	Chlorine is a fundamental building block of PVC. Chlorine can be used an indicator for the presence of chlorinated paraffins. Short chained chlorinated paraffins (SCCPs) are classified as a POP, and medium chained chlorinated paraffins (MCCPs) have been proposed for listing under the Stockholm convention as a POP.
Lead	Lead, like cadmium, was commonly used as a stabiliser in PVC. The use of lead in new PVC compounds voluntarily phased out by EU manufacturers by 2015. However, a restriction on its use in products was only introduced in 2024 through EU REACH. Lead stabilisers were commonly used in both flexible and rigid PVC formulations.
Zinc	Zinc oxide is a common additive in rubber products (as a vulcanising agent) and has been widely used as a pigment and filler in plastics.

Since XRF is a semi-quantitative screening method, the observed concentrations have been grouped into bands to aid interpretation. These bands and significance are given in Table 3.4.

The XRF data has also been used to highlight where substances classified with hazard statement codes may be present above relevant hazardous thresholds. Since XRF is semi-quantitative, the concentration of the element has been taken to be the same as the possible concentration of the classified substance (worst case compounds). For example, if antimony was detected at 12,000 mg/kg, the assumption is that antimony trioxide may be present at the same level. This could lead to an underestimation of the classified substance concentration, but is deemed suitable due to the semi-quantitative nature of XRF.

Any commentary on the hazardous status of a sample or a waste category based on the XRF data is not intended to provide an accurate HP assessment.

Table 3.4 XRF concentration bands

Concentration band	Justification
Less than 1,000 mg/kg	Classified or POPs substance unlikely to be present above relevant thresholds.
1,000 – 10,000 mg/kg	Classified or POPs substance potentially present above relevant thresholds.
10,000 – 100,000 mg/kg	Classified or POPs substance likely to be present above relevant thresholds. In the case of chlorine, >10,000 mg/kg suggests the sample may be PVC.
>100,000 mg/kg	Classified or POPs substance highly likely to be present above relevant thresholds. Indicates the sample is likely to be PVC when chlorine is >100,000 mg/kg.

3.3.2. Chemical screening

Sample selection

The results of the XRF scanning were used to select samples for further semi-quantitative chemical screening by VU. Samples were selected based on C&D category as well as the concentration of five main marker elements, bromine, antimony, chlorine, lead and arsenic, which known to be related to compounds classified with hazard statement codes. These elements are shown in Table 3.3.

Where possible samples were selected to retain the relative proportion of each waste category within the overall population of samples collected, since this reflected priority waste streams. However, additional samples were selected for some categories and sub-categories such as adhesives and sealants and extruded polystyrene (XPS) foam which were identified as a high priority by the EA. Likewise, fewer samples were selected for some categories of low interest (e.g. wood, plaster board, brick etc.).

These criteria were used to select 200 samples for chemical screening. Based on the findings of the chemical screening, samples were then selected for specific groups of quantitative analysis.

Semi-quantitative chemical screening

Screening of the 200 targeted samples was completed by VU. Pre-milled samples (25 mg) were first extracted with dichloromethane (DCM), and this was followed by sonication, shaking and centrifugation. The supernatant was collected, and the sample re-extracted with toluene. The extracts were then combined. As a minimum the extracts were diluted by a factor of 1000 as some chemical additives were at concentrations which would overload

the liquid chromatography (LC) column. This unavoidable approach does increase the threshold or limit of detection (LOD) and limit of quantification (LOQ). This is discussed further in Section 6.4.

Table 3.5 details the substance groups included in the screening. Chemical screening did not include PFAS or PCBs, as those substances are typically present at concentrations below the sensitivity of the analytical screening method (regardless of dilution). A full list of substances included in the screening suite is provided in Appendix A2 alongside a more detailed methodology.

Table 3.5 Screening groups and compounds

Group	Description
Plasticisers	14 phthalate compounds with and without hazard statement codes and six substitute plasticiser compounds not of the phthalate family with no associated hazard statement codes.
Organophosphate flame retardants	Ten phosphate-based flame retardants with a range of substances with and without hazard statement codes.
Brominated compounds	11 BFRs including the POPs classified compounds HBCD and PBDEs. Several compounds also have a range of hazardous classifications.
Chlorinated paraffins (CPs)	SCCPs and MCCPs.
Others	UV-328 and dechlorane plus.

Some phthalate compounds have been reported as a group as the individual substances cannot be distinguished from one another using the screening method due to similarities in their structure. In some cases, quantitative analysis can provide the concentration for each compound in a screening group individually, or as part of a smaller group with the same classification.

Screening was completed by high resolution mass spectrometry (liquid chromatography – quadrupole time-of-flight mass spectrometry - LC-QTOFMS) and covered a wide range of compounds including BFRs, OPFRs, UV-328, DCP, SCCPs, MCCPs (negative ion mode) and phthalates (positive ion mode). Identification of each group of chemicals and individual substances was based on sample mass and isotope patterns which were compared with analytical standards. The results of the chemical screening are presented using the four concentration bands outlined in Table 3.6.

Table 3.6 Screening result bands

Band
Not detected (ND)
Detected below 1,000 mg/kg
Detected between 1,000 and 10,000 mg/kg
Detected above 10,000 mg/kg

The screening data has been used to infer whether classified substances could be present above the associated HP thresholds for the associated hazard statement codes. An explanation of the 'likelihood' rating is provided in Table 3.7.

Table 3.7 Hazardous property threshold exceedance likelihood rating from chemical screening data

Probability of HP threshold exceedance	Description
N/A	No substance with relevant statement codes for the HP detected above 1,000 mg/kg.
Highly unlikely	HP threshold is well above the highest detected concentration.
Unlikely	HP threshold is above the highest detected concentration.
Possible	HP threshold is on the highest detected concentration or within the concentration band.
Likely	HP threshold is on or above the lowest detected concentration.
Highly likely	HP threshold is below the lowest detected concentration.

3.3.3. Quantitative analysis – Vrije Universiteit Amsterdam

Sample selection

The screening data was used to select samples to determine the quantitative concentration of several different substance groups. The analytical list of samples sent for quantitative analysis is provided in Table 3.8.

Table 3.8 VU quantitative analysis sample selection summary

Group	Number of samples	Description
BFRs and DCP	51	16 BFRs, including PBDEs and HBCD.
SCCPs and MCCPs	62	SCCPs are classified as a POP, and both SCCPs and MCCPs are classified with hazardous statement codes.
Phthalates and UV-328	67	19 phthalates including substances with and without hazard statement codes.
PFAS	20	32 PFAS group compounds, three of which are classified as POPs.
OPFRs	20	Nine common classified OPFRs and a range with no classification.

A complete breakdown of the analytical methodology for each analysis suite is provided in Appendix A3, however a brief breakdown for each analytical group is also provided in this section.

Quantitative analytical method

Quantitative testing was performed on the same extracts that were analysed during screening. This means they had been diluted by a factor of 1000 (and in the case of two samples by 10,000 due to very high matrix interference). This increases the LOD and LOQ but is difficult to avoid when some substances are present at very high concentrations that would swamp the detector.

Isotope labelled internal standards were added to each extract to quantify recovery. Analysis was performed with LC-QToF, in negative mode for BFRs and dechlorane plus, and in positive mode for the phthalates and UV-238. PFAS was analysed by LC-MS/MS in negative mode. External calibration was performed for the quantification. SCCPs and MCCPs were analysed by chlorine-enhanced APCI time-of-flight mass spectrometry (APCI-TOF-HRMS). Quantification was performed according to the deconvolution method described in Brandsma et al. (2017; 2019), using external calibration with a range of SCCPsor MCCPs mixtures.

Procedural blanks were included to reveal any contamination during handling, and sample preparations. Phthalates were found in the procedure blanks as phthalates are present in trace levels in extraction solvents and are also present in the air. For some phthalates the LOQs are therefore higher than for others. Quantification was performed with external calibration using analytical standards, and concentrations were corrected for internal standards. Mean recoveries of the internal standards for the phthalates were 79%, BFRs 101%, CPs 81%, and OPFRs 102%.

All quantitative data reported was above the LOQ of the quantitative method. If the concentration was below the LOQ, this is reported as a “less than (<)” concentration. A full

list of substances quantified alongside a more detailed methodology is provided in Appendix A3.

3.3.4. Quantitative BFR analysis – Fraunhofer Institute

Sample selection

Quantitative testing of select BFRs was also carried out by the Fraunhofer Institute (Fraunhofer) on 18 samples of insulation and two samples of expanding fillers to generate a larger dataset and provide a cross-laboratory comparison. Fraunhofer were used for this activity as they have specific experience of testing this matrix, which is complex, and they carried out real time method adjustments to ensure the highest possible data quality.

The list of all samples selected for each analysis suite is provided in the accompanying spreadsheet report. Seven of the insulation samples were also sent for screening and quantitative analysis at VU. This laboratory cross comparison provides information on the robustness of the quantitative testing both in terms of data comparability and differences.

Analytical method

Each sample was first screened using XRF spectrometry to determine an initial bromine concentration in the finely ground test material. To extract the target substances, 0.1 g of sample material was dissolved in toluene and then filtered. Some samples, where the matrix was partially or completely dissolved, required an additional cleanup step using ethanol. The internal standards were added to the filtered solution. A procedural blank containing the internal standard was prepared in parallel. The list of the substances analysed by Fraunhofer is provided in Table 3.9. A full list of substances quantified alongside a more detailed methodology is provided in Appendix A4.

Table 3.9 Substances included in quantitative analysis by Fraunhofer

Substance	Acronym
Polybrominated diphenyl ethers (mono to deca-BDE)	PBDEs
Tetrabromobisphenol A	TBBPA
Decabromodiphenyl ethane*	DBDPE
Hexabromocyclododecane	HBCD

*semi-quantitative

The analysis was carried out using GC-MS and quantification was then achieved using the external calibration and the internal standards for PBDEs, HBCD and TBBPA. DBDPE is very insoluble in most solvents and this impacts on the efficacy of the extraction process for both the sample and internal standard. To produce semi-quantitative results for DBDPE it was necessary to use deca-BDE as an alternative calibration standard. The residue precipitated and removed during the extraction process was also analysed by XRF to

provide a measure of the bromine extraction efficiency of the procedure and provide further context to the test findings.

Although not directly analysed, due to the analytical approach Fraunhofer was also able to provide an indication as to which samples contain polymeric flame retardant (PolyFR) based on the low bromine extraction results. PolyFR is a block copolymer of polystyrene and brominated polybutadiene, and as such is a large, immobile molecule that cannot be easily extracted.

3.3.5. Quantitative PCBs analysis – Marchwood Scientific Services

Sample selection

In total 25 samples were selected for quantitative PCB analysis which were predominantly selected from the adhesive and sealants category (21 samples) however, three flooring samples and one expanding filler sample were also included. The samples covered a range of sealants from different sources as well as different XRF chlorine concentrations. The samples were sent to Marchwood Scientific Services (MSS) for testing.

Analytical method

The analysis was undertaken using three common approaches to PCBs quantification which are outlined in Table 3.10.

Table 3.10 PCB testing approach

Compound	Congener
ICES6	Quantification of the six most commonly used PCB congeners (PCB-28, PCB-52, PCB-101, PCB-138, PCB-153 and PCB-180).
Total PCBs	The total concentration of PCBs based on the number of chlorine atoms (mono-, di-, tri-, etc. up to deca).
Dioxin-like PCBs (dl-PCBs)	Twelve PCB congeners quantified and adjusted for their toxic equivalent (TEQ) using assigned toxic equivalency factors (TEFs).

Each sample was analysed by MSS using High Resolution GC/MS – Isotope Dilution (USEPA 1668). A 1 g aliquot of each sample was taken from the <1 mm powder prepared by WRc and was extracted using Soxhlet extraction, using hexane as a solvent over 20 hours. The sample was spiked with an internal standard mixture (18 PCB congeners) and analysed, allowing recovery rates to be calculated for the dl-PCBs and the ICES6 PCBs. The LOQ for the 209 PCBs was 0.33 ng/kg, but for the individual PCBs quantified the LOQ varies. The TEQ for the dl-PCB concentration has been calculated using World Health Organisation (WHO) 2005 and 2022 TEFs.

4. Results

A total of 1,032 individual samples of construction and demolition waste were collected across 14 defined categories. This section provides a summary of the semi-quantitative XRF scanning and chemical screening data, and quantitative testing results collected on a range of C&D materials on a category basis. The sample details and analytical data is included in the excel spreadsheet that accompanies this report.

The spreadsheet also includes details of the classification of the substances discussed in the report and the associated hazard statement codes used throughout the study. The classification of substances is accurate at the time of writing and is subject to change.

Table 4.1 provides a graphical index highlighting in green which categories are of most relevance for the different classified substances included in this project. Arsenic (As), antimony (Sb), zinc (Zn) and lead (Pb) have been grouped, and one or more may be of relevance. PFAS, dechlorane plus and UV-328 were not present above the LOQ in any samples so are excluded from the table.

Table 4.1 Category index

Category	Page	PBDEs	CPs	BFRs	OPFRS	Phthalates	As, Sb, Zn, Pb
Insulation	31	✓	✓	✓	✓		✓
Plastic products	50	✓	✓	✓			✓
Pipes and ducting	62						✓
Flooring	71		✓			✓	✓
Doors and window frames	81						✓
Adhesives and sealants	91		✓			✓	
Cladding and wall panels	102		✓				✓
Rubber products	113						✓
Fixtures and fittings	121				✓		✓
Discarded construction materials	132						
Expanding fillers	143		✓		✓		
Roofing	156						
Wood	158						✓
Other	161						

4.1. Insulation

4.1.1. Sample collection

In total 188 insulation samples were collected from the C&D waste stream. These samples collected were divided into ten categories as outlined in Table 4.2.

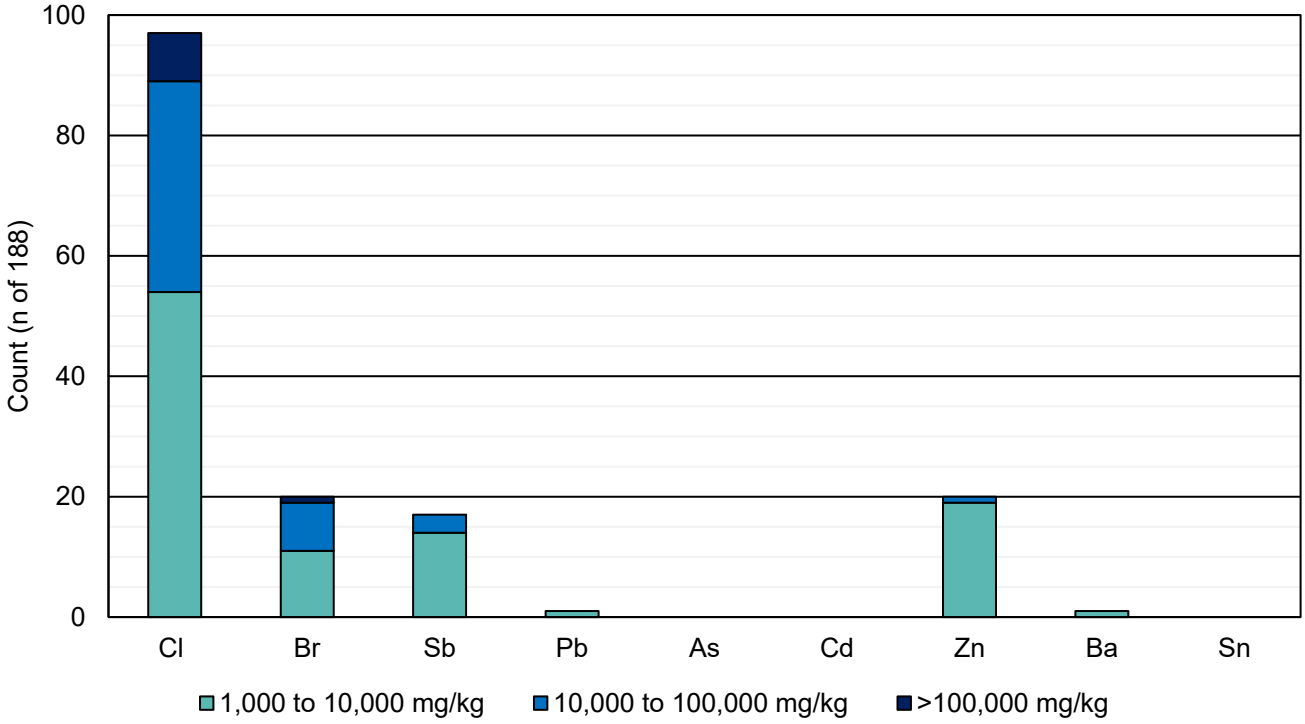
Table 4.2 Insulation categories

Category	Count	Description
Polyisocyanurate (PIR) insulation board	57	A rigid insulation board commonly manufactured with a foil layer on both faces, a brittle foam commonly white or cream in colour.
Fibre insulation	29	Commonly made from fibre glass, consisting of loose fibres often installed in rolls that can be pulled apart by hand.
Polyurethane (PU) insulation	38	Sponge like plastic-based insulation often with a visible open cell structure, found in a wide variety of colours.
Expanded polystyrene (EPS) insulation	17	A lightweight packaging and insulating material manufactured using beads of polystyrene within a mould which when subjected to heat or steam cause them to expand and fuse together. Commonly white in colour.
Foam rubber	17	Produced using sheeting, moulding, and extrusion processes from a range of source materials including liquid polymers, catalysts (to speed production) and blowing agents to create gas bubbles and surfactants to control bubble size. Can have an open or closed structure but are commonly black.
Extruded polystyrene (XPS) insulation	7	Rigid polystyrene insulation board with a smooth non-porous surface. Formed with controlled heat and pressure, the plastic mixture is forced through a die (extruded), then allowed to cool and expand into the desired shape. The resulting rigid foam board is then trimmed to the final product dimensions.
Mixed foam insulation	2	A combination of foams likely manufactured from foam manufacturing off-cuts and waste foam. Commonly multi-coloured in appearance and made of foam chips.
Other insulation	15	Non-foam insulation which does not fit a specific category, such as textiles, plasticised foils and cardboard etc.
Other foam insulation	6	Foam insulation which does not fit other specified categories.

4.1.2. XRF scanning

Each collected sample underwent XRF scanning in triplicate. The range of target element concentrations recorded for the insulation category are outlined in Figure 4.1

Figure 4.1 Insulation XRF scanning results



Bromine was identified above 1,000 mg/kg in 20 out of 188 insulation samples, nine of which had bromine above 10,000 mg/kg and one sample had bromine at greater than 100,000 mg/kg.

Of the samples with greater than 1,000 mg/kg bromine, nine also contained antimony at levels greater than 1,000 mg/kg, a strong indication that the bromine is present as a BFR. All but one of these products was rubberised foam insulation (pipe or sheet). Chlorine was also present at greater than 100,000 mg/kg in all eight rubberised foam samples. Chlorine concentrations of over 100,000 mg/kg likely indicate the sample is made from polyvinyl chloride (PVC), a polymer which is approximately 50% by weight chlorine.

This combination of bromine and chlorine is unusual, as typically only one halogenated compound is required for flame retardancy, and BFRs are uncommon in PVC formulations. Table 4.3 shows the bromine, chlorine and antimony content of samples with greater than 1,000 mg/kg bromine and antimony.

Table 4.3 Insulation samples with bromine and antimony >1,000 mg/kg

Sample	Category	Bromine (mg/kg)	Antimony (mg/kg)	Chlorine (mg/kg)
1122	Other insulation	12,877	2,970	220
2174	Foam rubber	39,237	1,616	219,682
4028	Foam rubber	53,893	3,677	260,632
4067	Foam rubber	51,295	3,530	264,850
4074	Foam rubber	8,424	10,717	29,770
4105	Foam rubber	72,844	13,948	265,382
4107	Foam rubber	40,063	1,559	250,791
4118	Foam rubber	7,960	1,191	74,566
5019	Foam rubber	111,701	39,618	100,676

The sample highlighted in orange was analysed using Fourier transform infrared (FTIR)[5] and was found to be neoprene. Neoprene is a synthetic rubber, also known as polychloroprene, and is produced from the monomer chloroprene. Chloroprene has the chemical formula C_4H_5Cl, meaning neoprene would be expected to contain 400,000 mg/kg chlorine. Due to the semi-quantitative nature of XRF and the difficulty in quantifying elements at high concentrations, it is reasonable to assume the samples with high chlorine and bromine may be neoprene rather than PVC.

Screening using XRF cannot distinguish which antimony compound is present, and therefore a worst-case scenario compound of antinomy trioxide must be assumed when discussing hazard properties. Antimony trioxide is classified as H351, which has a hazardous threshold of 10,000 mg/kg for HP 7, carcinogenic. Therefore, based on XRF analysis, two samples of insulation (4105 and 5019) may be classified as hazardous with HP 7.

Chlorine was present at levels greater than 1,000 mg/kg in 97 samples, with 54 containing between 1,000 and 10,000 mg/kg and 35 containing between 10,000 and 100,000 mg/kg. This level of chlorine is likely too low to indicate PVC (although as XRF is semi-quantitative this cannot be known for sure) and therefore may indicate the presence of chlorinated paraffins (CPs).

Zinc was detected above 1,000 mg/kg in 20 samples. It is considered that the most probably source is the presence of zinc compounds from fillers, pigments, blowing agents or as a flame retardant. Screening using XRF cannot distinguish which zinc compound is present, and therefore a worst-case scenario compound of zinc oxide must be used to

[5] This analysis was carried out by Shimadzu. FTIR analysis was carried out on eight samples as a technology demonstration.

comment on the potential hazardous properties of the samples. Zinc oxide is classified as H410 and has a hazardous threshold of 2,500 mg/kg, which ten samples were found to exceed.

4.1.3. Chemical screening

Sample selection

A total of 35 insulation samples were selected for semi-quantitative chemical screening (screening was carried out on 200 samples in total across all categories), retaining the same proportion of these samples as in the overall sample population (~18%). PIR and XPS foam were given a higher priority due to the suspected use of classified substances in these products. From the XRF analysis several foam rubbers samples were identified as samples of interest since 8 out of 12 samples contained bromine and antimony above 1,000 mg/kg, indicating the bromine is present as a BFR. Therefore, this material makes up a higher percentage of the insulation screening selection list. The breakdown of sample selection by category is provided in Table 4.4.

Table 4.4 Insulation sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Insulation (all)	188	35
PIR insulation board	57	7
Fibre insulation	29	2
PU insulation	38	10
EPS insulation	17	5
Foam rubber	17	4
XPS insulation	7	5
Mixed foam insulation	2	0
Other insulation	15	2
Other foam insulation	6	0

Screening results – POPs

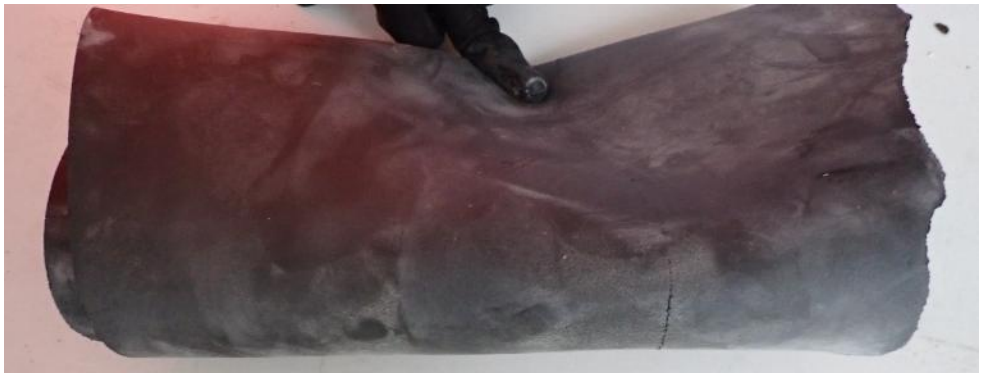
Of the six POPs compounds included in the screening compound list (HBCD, PBDEs, HBB, SCCP, UV-328 and DCP) both SCCPs and deca-BDE were detected. The details of the two samples found to contain these compounds are provided in Table 4.5. The levels of antimony seen during XRF analysis suggested a higher likelihood of POPs.

Table 4.5 Insulation POPs screening results

Sample	Description	XRF (mg/kg)			Screening concentration band (mg/kg)	
		Bromine	Antimony	Chlorine	SCCPs	Deca-BDE
4067	Foam rubber	51,295	3,530	264,850	1,000 – 10,000	10,000 – 100,000
5037	Other insulation	9,687	638	785	ND	<1,000

The sample containing SCCPs and Deca-BDE was a rubberised foam sheet material, identified to be neoprene through FTIR and highlighted during XRF analysis due to the high levels of bromine, chlorine and antimony. An image of this sample is provided in Photograph 4.1.

Photograph 4.1 Sample 4067 foam rubber– elevated SCCPs



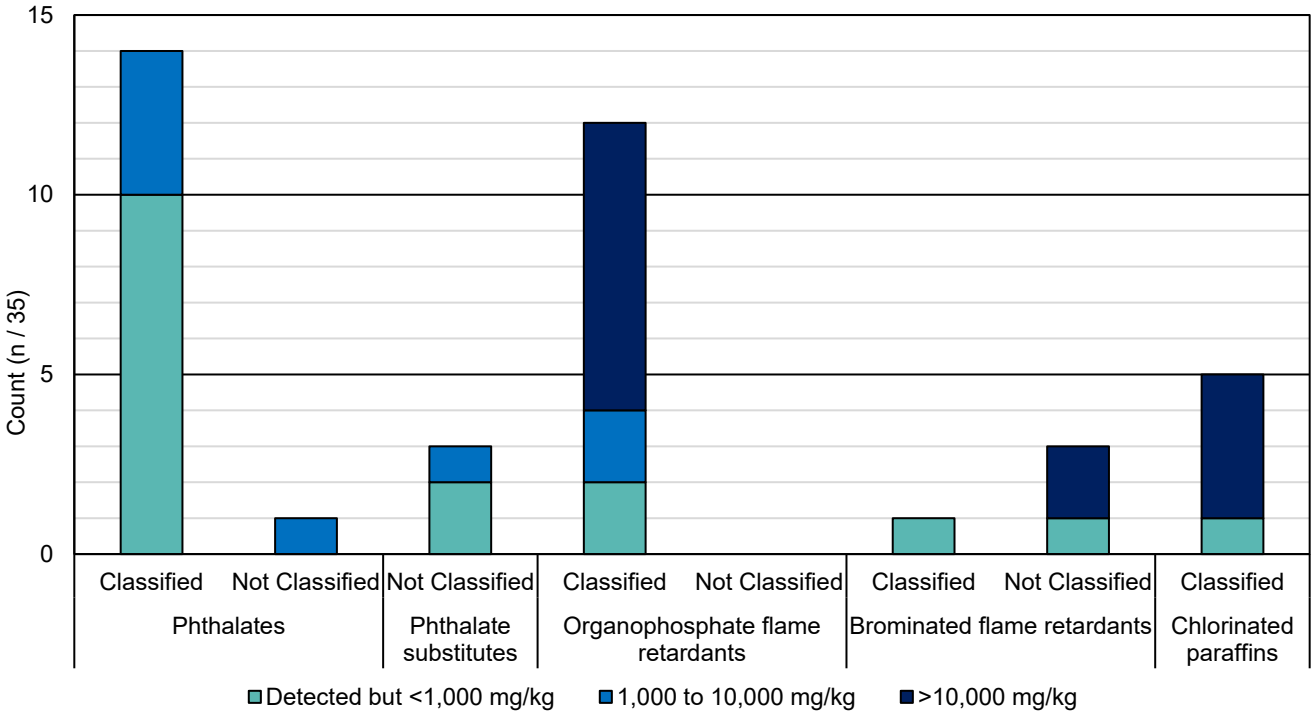
As the PBDE POPs threshold is 500 mg/kg, this sample with a deca-BDE concentration above 10,000 mg/kg was well above the threshold. The SCCPs concentration in this sample was identified between 1,000 and 10,000 mg/kg, and as the POPs threshold is currently 10,000 mg/kg, the screening data would suggest the material does not exceed this threshold. However, it may exceed the proposed future threshold of 1,500 mg/kg.

An additional sample containing deca-BDE was also detected but at the lowest concentration band (<1,000 mg/kg). As the recently lowered POPs concentration threshold for PBDEs is 500 mg/kg this sample may exceed this threshold and screening analysis alone does not provide a definitive answer.

Screening results – classified substances

Of the 35 insulation samples analysed, 14 had at least one substance with a hazard statement code present at over 1,000 mg/kg. A breakdown of the compounds detected by substance category is provided in Figure 4.2.

Figure 4.2 Insulation screening results



Four samples of rubberised foam were found to contain MCCPs at levels over 10,000 mg/kg. Due to the H410 classifications of MCCPs these samples are likely to exceed the HP 14 ecotoxic threshold of 2,500 mg/kg.

SCCPs are classified as both H410 and H351, meaning they have an additional hazardous threshold of 10,000 mg/kg for HP 7 carcinogenic.

All four samples had chlorine at concentrations over 10,000 mg/kg identified through XRF analysis. Table 4.6 shows the SCCPs and MCCPs concentration ranges and associated probability of exceeding the HP 7 and HP 14 hazardous thresholds.

Table 4.6 Insulation CPs screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration band (mg/kg)		HP threshold exceedance	
		Chlorine	SCCPs	MCCPs	HP 7	HP 14
4067	Foam rubber	264,850	1,000 – 10,000	>10,000	Unlikely	Highly likely
4074	Foam rubber	29,770	ND	>10,000	N/A	Highly likely
N14	Foam rubber	66,911	ND	>10,000	N/A	Highly likely
N16	Foam rubber	82,640	ND	>10,000	N/A	Highly likely

As MCCPs are proposed for listing under the Stockholm Convention by the UK, they could contribute to a CPs POPs exceedance in the future and impact the rate of POPs exceedance for this category.

LCCPs were not identified above 1,000 mg/kg in any of the insulation samples analysed.

Despite the known use of BFRs in insulation foams, chemical screening identified only four samples with detectable concentrations. Aside from the two samples found to contain deca-BDE, BFRs were detected in two other samples. One contained TBBPA below 1,000 mg/kg, and the other DBDPE at over 10,000 mg/kg. TBBPA is classified with H410 and so is likely present below the 2,500 mg.kg threshold.

Classified phthalates were detected in four samples at between 1,000 and 10,000 mg/kg. Of these, three contained an inseparable phthalate group consisting of DEHP and DIOP which are classified as H360. The other sample had an inseparable phthalate group which also contained a phthalate (DHUNP) classified as H360. As the HP 10, toxic for reproduction threshold for H360 is 3,000 mg/kg these samples have the potential to exceed the hazardous threshold.

Table 4.7 Insulation phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration band (mg/kg)		HP threshold exceedance
		Chlorine	DINP/DHUNP	DEHP/DNOP/ DIOP	HP 10
1194	PIR board	13,236	1,000 – 10,000	ND	Possible
7007	PU insulation	20,001	ND	1,000 – 10,000	Possible
N16	Foam rubber	82,640	ND	1,000 – 10,000	Possible
R044	Fibre insulation	240	ND	1,000 – 10,000	Possible

TCPP, an OPFR, was identified above 10,000 mg/kg in eight samples. As TCPP is classified as H302, H351, and H412 the respective hazardous thresholds of HP 6 (250,000 mg/kg), HP 7 (10,000 mg/kg) and HP 14 (250,000 mg/kg) have been used. Based on the screening data all eight samples would likely be above the HP 7 threshold. Two additional samples (1196 and 7040) made of polyurethane material were also found to contain TCPP between 1,000 and 10,000 mg/kg and are unlikely to exceed the HP 7 threshold. Due to the high threshold for HP 6 and HP 14, all samples are unlikely to exceed this. Table 4.8 shows the details of the ten samples. One sample (N2) was purchased as a new product for this study.

Table 4.8 Insulation OPFR screening results (classified substances >1,000 mg/kg)

Sample	Category	Screening concentration band (mg/kg)	HP threshold exceedance		
		TCPP	HP 6	HP 7	HP 14
1084	PU insulation	>10,000	Unlikely	Likely	Unlikely
1100	PIR board	>10,000	Unlikely	Likely	Unlikely
1194	PIR board	>10,000	Unlikely	Likely	Unlikely
1196	PU insulation	1,000 – 10,000	Highly unlikely	Unlikely	Highly unlikely
2060	PIR board	>10,000	Unlikely	Likely	Unlikely
2161	PU insulation	>10,000	Unlikely	Likely	Unlikely
2190	PIR board	>10,000	Unlikely	Likely	Unlikely
7007	PU insulation	>10,000	Unlikely	Likely	Unlikely
7040	PU insulation	1,000 – 10,000	Highly unlikely	Unlikely	Highly unlikely
N2	PIR insulation board	>10,000	Unlikely	Likely	Unlikely

4.1.4. Quantitative analysis

Sample Selection

A total of 15 insulation samples were selected for quantitative testing by VU. Justification for inclusion is provided in Table 4.9.

Table 4.9 Insulation sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	15/51	Insulation materials were a key category of interest for BFR quantitative testing with EPS and XPS materials being a particular focus. The selection included both samples where BFRs were detected above 10,000 mg/kg in the screening analysis. As TBBPA was identified at a concentration of <1,000 mg/kg below the associated H410 contribution threshold it was not selected for quantitative testing.
SCCPs and MCCPs	12/62	CPs quantitative testing was focussed on the insulation category. All five samples with CPs detected above 1,000 mg/kg were selected. Additional samples were selected where no CPs were identified, but which also had an elevated chlorine content or had an increased likelihood of having FR present (e.g. foam rubber).
Phthalate and UV-328	0/67	No samples were selected for phthalate testing due to prioritisation of other waste categories. As insulation is not designed to be resistant to UV damage, UV-328 was also not considered as a factor in sample selection.
PFAS	1/20	This was a low priority category for this group of substances as insulation do not typically require the associated properties PFAS provides (e.g. water/stain resistance), however a single roofing tile with internal insulation was selected.
OPFRs	5/20	Several samples where hazardous OPFRs were identified were selected for testing. All samples selected contained TPP at both >0.1% and >1% as well as a single sample containing TNBPP with a concentration >0.1%.

Brominated flame retardants

The results of the quantitative BFR analysis are provided in Table 4.10. Of the 15 insulation samples analysed four were found to contain BFRs above the LOQ. Three samples were found to contain Deca-BDE two of which had a concentration above the current POPs threshold of 500 mg/kg (samples 4067 and 5037). HBCD was not detected in any samples of insulation above the LOQ of between 130 and 190 mg/kg.

Table 4.10 Insulation BFR quantitative results

Sample	Category	XRF (mg/kg)		Classified POPs (mg/kg)		Classified (hazard statement codes) (mg/kg)	Non-Classified (mg/kg)
		Bromine	Antimony	tetra- to hepta-BDE	deca-BDE	TBBPA	DBDPE
1051	EPS insulation	5,899	<18	<500	<150	<310	<720
1096	EPS insulation	11,813	<18	<500	<150	<310	<720
1114	PIR board	2,589	<18	<500	<150	<310	<720
1122	Other insulation	12,877	2,970	<500	<150	<310	<720
1216	EPS insulation	6,470	<18	<500	<150	<310	<720
1226	EPS insulation	3,521	<18	<500	<150	<310	<720
2131	XPS insulation	1,411	<18	<550	<170	<340	<790
4067	Foam rubber	51,295	3,530	<440	53,600	<270	<620
4074	Foam rubber	8,424	10,717	<570	<180	<350	2,020
5037	Other insulation	9,687	638	<480	920	<290	<680
7007	PU insulation	18,042	<18	<550	<170	<340	<790
7015	EPS insulation	52,38	<18	<570	<180	<350	<830
N6	XPS insulation	663	<18	<550	260	<330	<780
N8	XPS insulation	3,441	<18	<570	<170	<350	<810
R044	Fibre insulation	2,591	980	<530	<160	<320	<750

Note: Orange shading above LOQ, green above POPs threshold

A single sample (4074) was found to contain DBDPE at a concentration of 2,020 mg/kg. DBDPE is not classified with any hazard statement codes but has been assessed to be very persistent and very bioaccumulative (vPvB) by the European Chemicals Agency (ECHA), so may be a substance of interest in the future.

The quantitative analysis does not account for the level of bromine in most samples. Two samples contained close to or above 1,000 mg/kg antimony, indicating the presence of BFRs. This may be a result of other brominated flame retardants being present, for example TBBPA derivatives. It may also indicate analytical difficulties in extracting and quantifying some BFRs, which may potentially be more difficult in products with high concentrations than mixed waste with lower concentrations.

It should be noted that the relatively high LOQs are due to high dilution rates used by the laboratory to protect instrumentation and prevent overwhelming the mass spectrometer. This is discussed in detail in Section 6.4.

Dechlorane plus

Dechlorane plus was not detected above the LOQ of between 70 and 80 mg/kg in any of the samples analysed.

Chlorinated paraffins

The results of the quantitative CPs analysis are provided in Table 4.11.

Table 4.11 Insulation chlorinated paraffin quantitative results

Sample	Category	XRF (mg/kg)	Quantitative concentration (mg/kg)	
		Chlorine	SCCPs	MCCPs
1194	PIR board	13,235	<700	2,800
1216	EPS insulation	59	<100	<100
2084	PU insulation	9,943	<600	<600
2085	PU insulation	3,675	<600	<600
2161	PU insulation	26,4850	<600	<600
4067	Foam rubber	29,770	2,200	164,000
4074	Foam rubber	25,008	<600	249,000
7007	PU insulation	20,000	<600	<600
7040	PU insulation	8,462	<600	7,600
N2	PIR board	32,874	<600	<600
N14	Foam rubber	66,911	<600	214,800
N16	Foam rubber	82,640	<600	160,100

Note: Orange shading above LOQ, red above a hazardous property threshold

Of the 12 insulation samples sent for quantitative CPs analysis a single foam rubber sample had a SCCPs concentration above the LOQ. The concentration quantified in this sample was 2,200 mg/kg, which is below the current UK POPs threshold of 10,000 mg/kg. It is however above the EU threshold of 1,500 mg/kg and so may potentially exceed future UK thresholds. This sample also was found to contain high levels of deca-BDE, exceeding the POPs threshold.

MCCPs were detected in four samples with concentrations above 10,000 mg/kg. As MCCPs are proposed for listing under the Stockholm convention by the UK, the inclusion of them in a POPs assessment could significantly impact the exceedance rate of this category in the future. All four samples were made of rubberised foam material. Two of these samples (N14 and N16) were purchased new for the project, suggesting that if MCCPs were to be listed as a POP, products placed on the market today may exceed an allocated threshold.

Two further samples (1194 and 7040) which had not been identified as containing CPs in the screening analysis were found to have a MCCPs concentration above 1,000 mg/kg (2,800 mg/kg and 7,600 mg/kg).

As both SCCPs and MCCPs have a hazardous classification of H410, all six samples with quantified MCCPs had a concentration above the associated HP 14 hazardous threshold (2,500 mg/kg). The one sample which contained both SCCPs and MCCPs had SCCPs concentrations above the HP 14 contribution threshold (1,000 mg/kg) but below the hazardous threshold and therefore would not have exceeded this threshold without the contribution from the much larger MCCPs concentration.

PFAS

The single sample sent for PFAS analysis (5037 – ceiling tile with insulation) did not contain any compounds included in the PFAS suite above the LOQ of 5 µg/kg.

Organophosphates flame retardants

The results of the quantitative organophosphate flame retardants (OPFRs) analysis are provided in Table 4.12.

Table 4.12 Insulation organophosphate flame retardants quantitative results

Sample	Category	Classified (hazard statement codes) (mg/kg)	Non-Classified (mg/kg)
		TCPP	TDCIPP
1084	PU insulation	33,320	<120
1194	PIR board	33,250	<160
1196	PU insulation	<220	<130
2161	PU insulation	8,700	1,820
7040	PU insulation	1,500	<150

Note: Orange shading above LOQ, red above a hazardous property threshold

Of the five insulation samples sent for OPFR analysis TCPP was detected in four. Two samples exceed the 10,000 mg/kg threshold for HP 7, but are both under the 250,000 mg/kg threshold for HP 6 and HP 14.

Sample 2161 was the only sample of all 20 sent for OPFRs analysis where TDCIPP was detected above the LOQ and was also the only sample identified to contain this compound

in the screening analysis of 200 samples. TDCIPP is classified as H410[6] and H351, so although it is below the thresholds for both (2,500 mg/kg and 10,000 mg/kg respectively), it exceeds the H410 cut off limit of 1,000 mg/kg for inclusion in the HP 14 calculation.

Brominated flame retardants (Fraunhofer)

Due to the suspected high potential for BFRs to be present in insulation materials, 18 additional samples were submitted to the Fraunhofer Institute (Fraunhofer) for quantitative analysis (including nine samples also analysed by VU). Fraunhofer are experienced in quantifying BFRs, particularly in insulation materials. Of the 18 insulation samples analysed, PBDEs were detected above the LOQ in 13 samples as outlined in Table 4.13.

Comparing the data to the POPs threshold of 500 mg/kg for the sum of POPs classified PBDEs (tetra-, penta-, hexa-, hepta- and deca-BDEs), seven samples exceeded this threshold due only to deca-BDE concentrations.

HBCD was detected in a single sample, however, the exact concentration was not determined, and a minimum concentration of 763.5 mg/kg was reported. Analysis of HBCD has been problematic for Fraunhofer in the past. HBCD can be destroyed using high injection temperature during analysis, but Fraunhofer have developed a method to account for this and do not believe this is the case for under reporting in the foam sample. Instead, it is possible that the discrepancy is potentially due to the foam matrix, where difficulties have been found in quantifying HBCD, and the potential for interference from other BFRs. Although the exact concentration cannot be determined, if HBCD is present it would show in the Fraunhofer analysis, and so it is reasonable to concluded only the one sample analysed contained HBCD above the LOQ.

As the associated POPs threshold for HBCD is 1,000 mg/kg the reported minimum concentration is below the threshold, but it is possible the actual concentration is greater and could be above the threshold. HBCD is also classified as H361, H362, H400 and H410, and so it is possible the concentration in the sample exceeds the 2,500 mg/kg threshold for HP 14.

Two additional common BFR compounds were also analysed in the suite, TBBPA and DBDPE. TBBPA was not identified above the LOQ in any of the samples analysed but DBDPE was detected in six samples.

Four of the samples with DBDPE were made of a rubberised foam material however the sample with the highest DBDPE concentration was a unique form of fibrous sheeting (2,121 mg/kg). The DBDPE analysis is semi-quantitative as this compound is highly insoluble, meaning it cannot be effectively extracted from the polymer matrix and quantified, despite strenuous efforts to improve the analytical method. DBDPE does not

[6] Only H351 is harmonised. There are notifications for both H411 and H410, with H410 selected for this study as a worst case.

have any hazard statement codes and has not been proposed for listing under the Stockholm Convention.

Table 4.13 Fraunhofer insulation BFR results (with LOQ)

Sample	Category	XRF (mg/kg)		Classified (POPs) (mg/kg)			Classified (hazard statement codes) (mg/kg)		Non-Classified (mg/kg)		
		Bromine	Antimony	tetra- to hepta-BDE	deca-BDE	HBCD	octa-BDE	TBBPA	mono to tri-BDE	nona-BDE	DBDPE*
1051	EPS insulation	5,899	<18	<7.50	<2.50	> 763.5	<2.00	<85	<1.25	<2.50	<2.5
1114	PIR board	2,589	<18	<7.50	<2.50	<95	<2.00	<85	<1.25	<2.50	5.66
1122	Other insulation	12,877	2,970	<7.50	5.53	<95	<2.00	<85	<1.25	<2.50	2,121
2131	XPS insulation	1,411	<18	<7.50	<2.50	<95	<2.00	<85	<1.25	<2.50	<2.5
2153	XPS insulation	576	<18	<7.50	<2.50	<95	<2.00	<85	<1.25	<2.50	<2.5
2174	Foam rubber	39,237	1,616	<7.50	30.8	<95	<2.00	<85	<1.25	<2.50	8.6
4028	Foam rubber	53,893	3,677	<7.50	128,480	<95	55.9	<85	<1.25	2,021	<2.5
4067	Foam rubber	51,295	3,530	<7.50	160,273	<95	66.4	<85	<1.25	3,940	<2.5
4074	Foam rubber	8,424	10,717	<7.50	22.8	<95	<2.00	<85	<1.25	<2.50	<2.5
4105	Foam rubber	72,844	13,948	<7.50	51,991	<95	8.83	<85	<1.25	1,028	6.53
4107	Foam rubber	40,063	1,559	<7.50	62,009	<95	8.38	<85	<1.25	2,785	6.41
4118	Foam rubber	7,960	1,191	<7.50	166	<95	<2.00	<85	<1.25	7.51	363.4
5019	Foam rubber	111,701	39,618	<7.50	100,808	<95	42.2	<85	<1.25	2,610	<2.5
5037	Other insulation	9,687	638	<7.50	4,012	<95	2.35	<85	<1.25	84.7	<2.5
N5	EPS insulation	789	<18	<7.50	59.4	<95	<2.00	<85	<1.25	2.91	<2.5
N6	XPS insulation	663	<18	<7.50	296	<95	<2.00	<85	<1.25	13.8	<2.5
N8	XPS insulation	3,441	<18	<7.50	86.6	<95	<2.00	<85	<1.25	3.17	<2.5
N17	XPS insulation	486	<18	<7.50	861	<95	<2.00	<85	<1.25	28.2	<2.5

Note: Orange shading above LOQ, red shading above a hazardous threshold, green shading above POPs threshold, *semi-quantative

To determine extraction efficiency of the brominated compounds analysed, the samples underwent XRF analysis before and after extraction as outline in the Fraunhofer analysis approach (Section 3.4.3). The results of this analysis are provided in Table 4.14.

Samples where a high extraction efficiency was achieved but only low concentrations of the identified compounds were quantified potentially indicates that the presence of an unidentified soluble BFR being present within the sample.

Samples where a low bromine extraction efficiency were achieved and none of the target BFRs were detected were thought to contain Polymeric Flame Retardants (PolyFR). This is a block copolymer of polystyrene and brominated polybutadiene, meaning it is a very large molecule and is virtually impossible to extract and cannot be quantified (details outlined in Section 6.4).

Table 4.14 Fraunhofer insulation extraction efficiency

Sample	Category	Input bromine (mg/kg)	Output bromine (mg/kg)	Extraction efficiency (%)
1051	EPS insulation	5,899	14	99.8
1114	PIR board	2,589	524	79.8
1122	Other insulation	12,877	7,119	44.7
2131	XPS insulation	2,798	1,095	60.9
2153	XPS insulation	>4,000	4,554	0
2174	Foam rubber	39,237	39,360	0
4028	Foam rubber	53,893	545	99
4067	Foam rubber	51,295	756	98.5
4074	Foam rubber	8,424	227	97.3
4105	Foam rubber	72,844	537	99.3
4107	Foam rubber	40,063	735	98.2
4118	Foam rubber	796	92	88.4
5019	Foam rubber	111,701	830	99.3
5037	Other insulation	15,868	78	99.5
N5	EPS insulation	789	131	83.3
N6	XPS insulation	663	519	21.8
N8	XPS insulation	3,441	226	93.4
N17	XPS insulation	486	346	28.8

Note: for samples where a zero percent extraction efficiency was measured, the bromine content after extraction was slightly higher than input.

4.1.5. Summary

Waste insulation was of particular interest in this study due to the historic use of flame retardants in these materials. Through this study, seven samples containing deca-BDE over the POPs threshold of 500 mg/kg were identified. In addition to this, MCCPs and organophosphate flame retardants with hazard statement codes were also detected in this material category. MCCPs were particularly prevalent in foam rubber insulation (possibly neoprene) and were quantified at levels over 100,000 mg/kg in four samples.

HBCD, previously understood to be present in insulation was only detected in one sample, although there were challenges in quantifying this substance. SCCPs were quantified in a single sample below the current POPs threshold.

Table 4.15 summarises the results for the quantitative analysis of insulation samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Zinc was detected using XRF scanning at levels potentially above hazardous thresholds for zinc oxide in 5% of samples collected. These samples were mostly foam rubber insulation. Table 4.16 summarises the results of the XRF scanning of all items sampled, highlighting the relative prevalence for the four elements possibly present in compounds classified with hazard statement codes.

Table 4.15 Summary of the prevalence of classified substances in insulation

Substance	Relative prevalence	Commentary
deca-BDE	High	Quantitative analysis identified seven samples with deca-BDE above the 500 mg/kg POPs threshold. Rubber foam was the category with most exceedances.
tetra- to hepta-BDE	Low	
HBCD	Medium	Only one sample was found to contain HBCD, however analytical challenges made quantification difficult. There is a question over the ability to detect and quantify HBCD in foams.
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	A neoprene rubber sample was identified with a SCCPs concentration below the current threshold, but potentially above future thresholds.
MCCPs	High	Concentrations of MCCPs over 100,000 mg/kg were quantified in four rubber foam samples. Two other samples (one PIR and one rubber) had levels between 2,000 and 8,000 mg/kg.
Classified BFRs	Low	
Classified phthalates	Low	
Classified OPFRs	High	TCPP, classified as H302, H351 and H412 was detected in three samples above the associated HP 7 threshold.

Table 4.16 Summary of key elements in insulation

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	Low	
Zinc	Medium	Zinc was detected at levels above the zinc oxide hazardous threshold for HP 14 in ten samples (~5% of samples) using XRF scanning.

Table 4.17 shows how many samples from each category of insulation exceeded relevant thresholds. Of all insulation types, the foam rubber (some of which may be neoprene) is where the greatest number of exceedances occurred, with five of 16 samples containing

PBDEs above the POPs threshold, with a number also containing CPs and/or zinc above hazardous property thresholds. PIR and PU insulation.

Table 4.17 Insulation samples exceeding thresholds by category

Category	Total collected (n)	Samples exceeding POPs thresholds (n)		Samples exceeding hazardous property thresholds (n)		
		Quantitative		Quantitative		XRF
		PBDEs	SCCPs	CPs	TCPP	Zinc
Insulation (all)	188	7 (24)	0 (12)	6 (12)	2 (5)	10
PIR insulation board	57	0 (1)	0 (2)	1 (2)	1 (1)	0
Fibre insulation	29	0 (1)	-	-	-	2
PU insulation	38	0 (1)	0 (5)	1 (5)	1 (4)	0
EPS insulation	17	0 (6)	0 (1)	0 (1)	-	0
Foam rubber	17	5 (8)	0* (4)	4 (4)	-	8
XPS insulation	7	1 (5)	-	-	-	0
Mixed foam insulation	2	-	-	-	-	0
Other insulation	15	1 (2)	-	-	-	0
Other foam insulation	6	-	-	-	-	0

Note: One sample was found to contain over 700 mg/kg HBCD, with the exact concentration unable to be quantified, and as such may contain HBCD above the POPs threshold of 1,000 mg/kg as bromine was detected at over 5,000 mg/kg using XRF.

*One sample above possible future UK threshold of 1,500 mg/kg.

4.2. Plastic Products

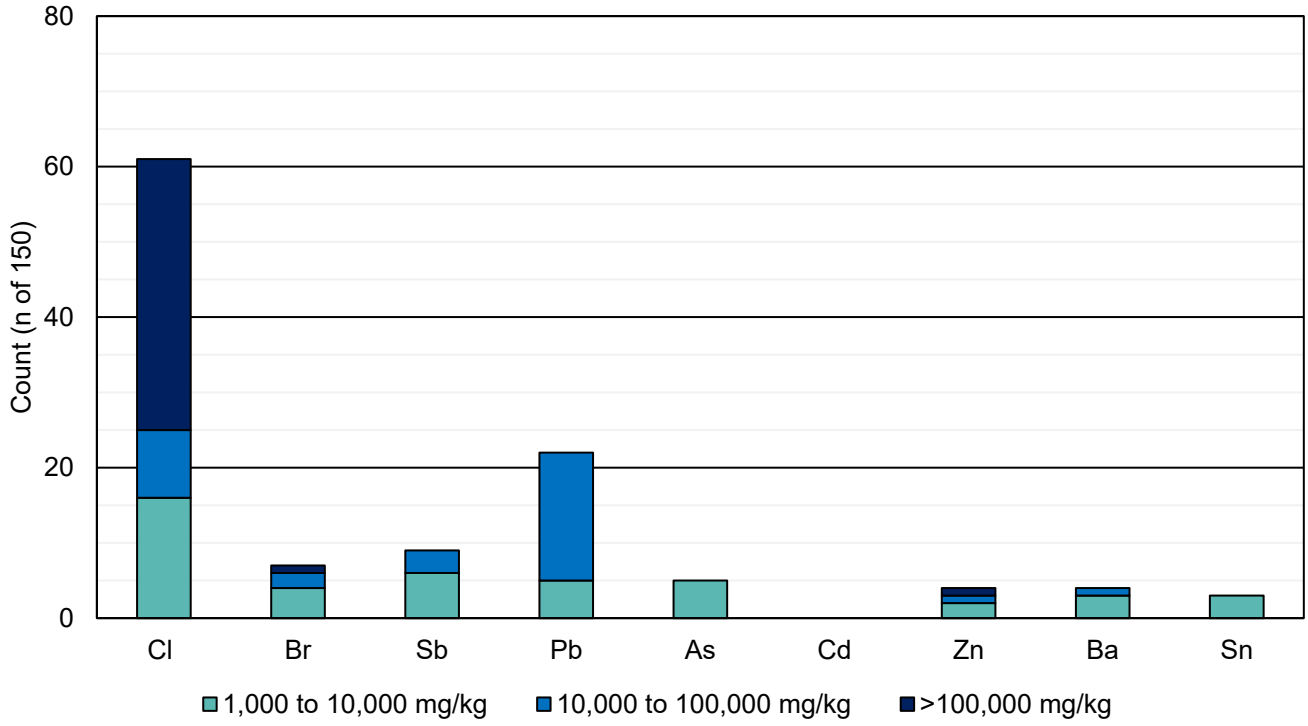
4.2.1. Sample collection

A total of 150 plastic product samples were collected during the sampling programme. Due to the wide range of individual items found, the samples collected were not divided into further sub-categories. Examples of products from this category included signage, cable skirting and wall brackets, as well as plastics that were of unknown origin. Plastic material was abundant at most sites but as the origin of many items could not be identified, they were not prioritised for collection after the visit to Site 1 following discussions with the EA.

4.2.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded in the plastics category are outlined in Figure 4.3.

Figure 4.3 Plastic XRF scanning results



Seven plastic samples were found to contain bromine above 1,000 mg/kg, two of which (samples 3088 and 4102) had a bromine concentration above 10,000 mg/kg and one above 100,000 mg/kg (sample 1080). The sample with a bromine concentration identified above 100,000 mg/kg is shown in Photograph 4.2. This sample also contained over 35,000 mg/kg antimony, indicating the likely presence of BFRs.

Photograph 4.2 Sample 1080 plastic casing – bromine 113,000 mg/kg

Of the nine samples with greater than 1,000 mg/kg antimony only four correlated with elevated bromine concentrations. The remaining five samples with antimony above 1,000 mg/kg also contained chlorine above 10,000 mg/kg, suggesting the antimony may be present as a synergist for both chlorinated and brominated flame retardants. Table 4.18 provides the XRF data for plastic samples with more than 1,000 mg/kg antimony measured.

Table 4.18 Plastic product samples with antimony >1,000 mg/kg

Sample	Description	Antimony (mg/kg)	Bromine (mg/kg)	Chlorine (mg/kg)
3106	Join sealing tape	75,163	5	76,530
1080	Plastic casing	35,531	112,992	7,962
3088	Fire exit sign case	13,070	49,125	1,898
4102	Tray	5,622	17,734	41
1209	Corrugated sheet	5,226	1	304,603
5033	Fire exit sign	4,642	1	305,296
4143	Filing cabinet divider	1,929	6,382	41
1055	Temporary walkway	1,338	141	24,292
4100	Signage	1,110	1	282,033

Antimony is likely to be present as antimony trioxide, a substance used as a synergist for flame retardancy alongside other halogenated compounds. Antimony trioxide is classified as H351 with a threshold of 10,000 mg/kg for HP 7, carcinogenic. Since three samples contained over 10,000 mg/kg antimony, these samples would likely exceed the HP 7 threshold.

Of the plastic samples analysed 61 (41%) had a chlorine concentration above 1,000 mg/kg. Over half these sample had a chlorine concentration above 100,000 mg/kg, suggesting a number of these products may be made from PVC. Unlike insulation, no

samples with greater than 10,000 mg/kg chlorine contained bromine levels above 1,000 mg/kg. This suggests that the combination of bromine and chlorine is an indication of neoprene, and PVC is unlikely to contain bromine.

Lead was detected in five samples between 1,000 and 10,000 mg/kg and above 10,000 mg/kg in 17 samples (11%). As 13 of these 17 samples (75%) also contained chlorine above 100,000 mg/kg, it would indicate the lead is present as a stabiliser in PVC products.

Lead (as lead compounds) is classified as H360 and H410[7], meaning it has HP thresholds of 3,000 mg/kg for HP 10, toxic for reproduction, and 2,500 mg/kg for HP 14, ecotoxic, respectively. Despite the semi-quantitative nature of the handheld XRF analysis a concentration over 10,000 mg/kg would put the sample well above these hazardous thresholds. In total, 19 samples contained lead at levels above thresholds for both HP 10 and HP 14.

Of the five samples with arsenic concentration above 1,000 mg/kg, four contained chlorine above 100,000 mg/kg and lead above 10,000 mg/kg indicating these are likely to be PVC and that the arsenic is present alongside lead (Table 4.19). Arsenic was also historically used as a stabiliser, although to a lesser extent than lead. The remaining sample with an arsenic concentration greater than 1,000 mg/kg did have elevated lead (17,000 mg/kg) but low chlorine (<400 mg/kg) so it is unclear as to why these elements are present. Table 4.19 shows the samples with arsenic present above 1,000 mg/kg.

Table 4.19 Plastic product samples with arsenic >1,000 mg/kg

Sample	Description	Arsenic (mg/kg)	Chlorine (mg/kg)	Lead (mg/kg)
4133	Join sealing tape	2,798	397	17,111
R005	Plastic casing	1,239	127,421	25,951
1021	Fire exit sign case	1,211	335,330	34,242
5016	Tray	1,110	317,321	23,950
5068	Corrugated sheet	1,063	276,662	25,377

XRF cannot determine which arsenic compound is present, and so a worst-case compound of arsenic trioxide has been used to comment on the potentially hazardous nature of these samples. Arsenic trioxide has several hazardous statement codes. The ones of relevance at the concentrations determined using XRF are H300, H350, H360 and H410. H300 and H350 have a hazardous threshold of 1,000 mg/kg for HP 6, acute toxicity, and HP 7, carcinogenic respectively, H360 has a hazardous threshold of 3,000 mg/kg for

[7] Lead compounds also carry H332, H302, H373 and H400 however as these have relatively high thresholds (>100,000 mg/kg) that are highly unlikely to be exceeded, they have not been included in the discussion.

HP 10, toxic for reproduction and H410 has a hazardous threshold of 2,500 mg/kg for HP 14, ecotoxic. Therefore, these five samples would exceed the threshold for HP 6 and HP 7 but are less likely to exceed the threshold for HP 10. The HP 14 threshold is exceeded by one sample, however all others exceed the 1,000 mg/kg cut off limit to be included in the HP 14 assessment.

4.2.3. Chemical screening

Sample selection

Disposable plastic goods were not considered a high priority category compared with other products with a longer use span, and 22 longer life products were selected for quantitative analysis. This represented 11% of all samples selected for chemical screening, whereas plastics represented 15% of all samples taken.

The samples selected included all plastic samples with elevated bromine (>1,000 mg/kg) as well as samples with a range of chlorine, lead and arsenic concentrations.

Screening results – POPs

Of the POPs compounds included in the screening list both SCCPs and deca-BDE were detected. The details of the samples identified as containing these compounds are provided in Table 4.20.

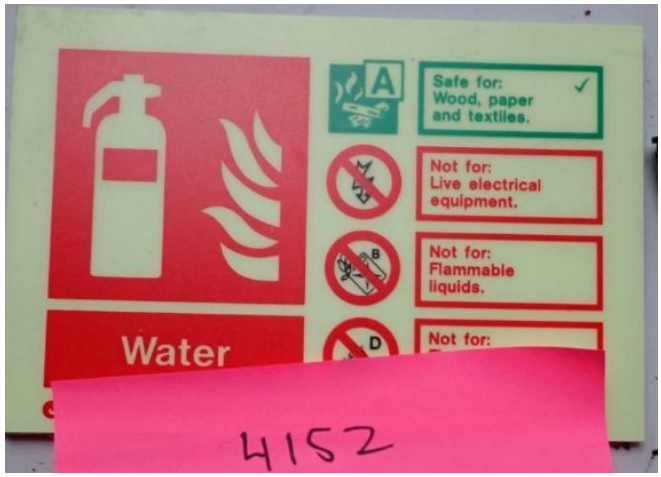
Table 4.20 Plastic POPs screening results

Sample	Description	XRF (mg/kg)			Screening concentration band (mg/kg)	
		Bromine	Antimony	Chlorine	SCCPs	Deca-BDE
4102	Tray	17,734	5,622	<41	ND	1,000 – 10,000
4143	Filing cabinet divider	6,382	1,929	<41	ND	1,000 – 10,000
4152	Fire signage	7	<18	459,256	1,000 – 10,000	ND

SCCPs were only detected in a single sample (4152 – fire exit sign). An image of the sample is provided in Photograph 4.3.

As the concentration of SCCPs was found to be between 1,000 and 10,000 mg/kg this sample would likely not exceed the POPs threshold of 10,000 mg.kg but may be above a predicted future POPs threshold (1,500 mg/kg). MCCPs were also detected in this sample between 1,000 and 10,000 mg/kg. As MCCPs are recommended for listing under the Stockholm convention they could contribute to a CPs POPs exceedance of this sample in the future.

Photograph 4.3 Sample 4152 fire signage containing elevated SCCPs



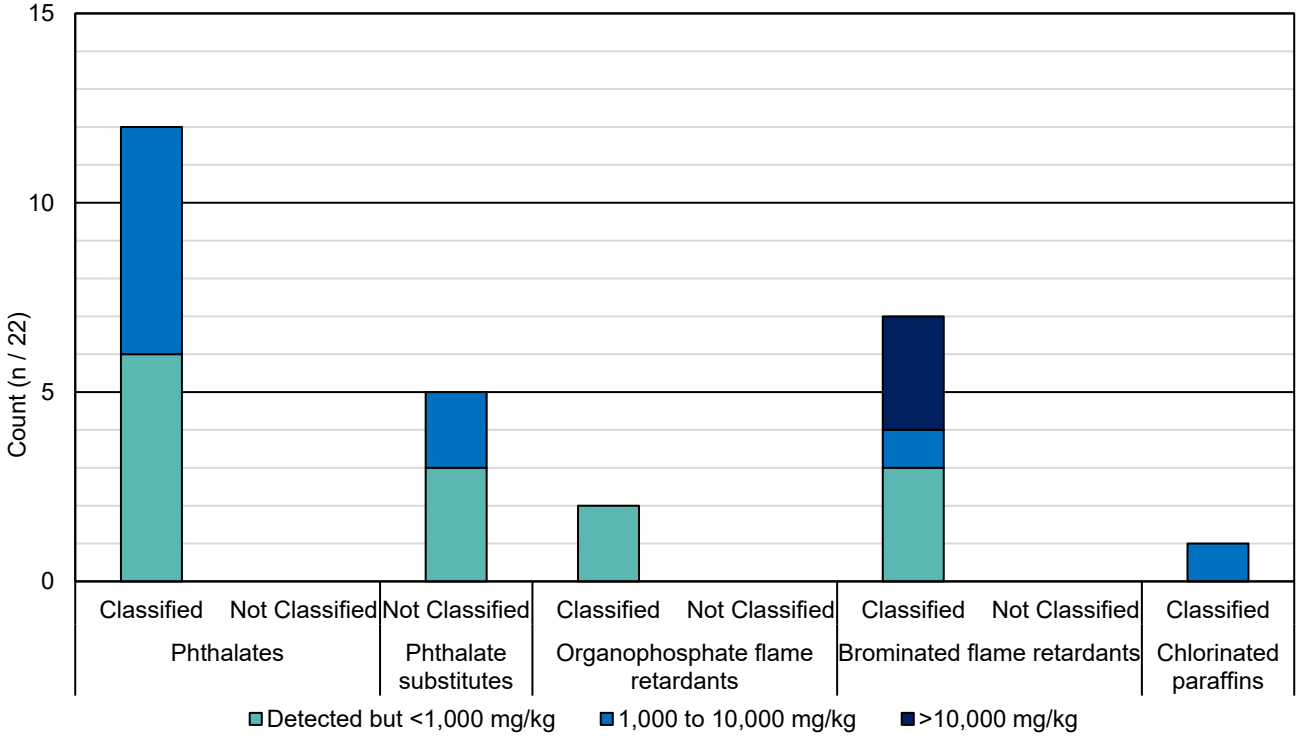
Two samples of hard plastic were also found to contain deca-BDE between 1,000 and 10,000 mg/kg which is above the current PBDE POPs threshold of 500 mg/kg.

No other sample was found to contain listed POPs. A sample (1080 – casing) was however found to contain two compounds listed by ECHA as persistent, bioaccumulative and toxic (PBT) above 10,000 mg/kg (2,4,6-TBP and DBDPE).

Screening results – classified substances

Of the 22 samples analysed 16 samples had at least one hazardous substance detected. A breakdown of the compounds detect by substance category is provided in Figure 4.4.

Figure 4.4 Plastic screening results



The concentration of both SCCPs and MCCPs was identified between 1,000 and 10,000 mg/kg for one sample (4152). A definitive hazardous classification cannot be determined, as both CPs have a classification of H410 which has a HP 14, ecotoxic, contribution threshold of 1,000 mg/kg and an additive hazardous threshold of 2,500 mg/kg. It is therefore likely that the sample is above or very close to the HP 14 threshold. LCCPs were not identified in any of the plastic samples analysed.

Two classified BFRs, TBBPA (H350, H400, H410) and 2,4,6-TBP (H302, H317, H319, H400, H410), were detected at levels greater than 1,000 mg/kg, in four samples. Due to the hazardous thresholds, H350 and H410 are the statement codes of relevance. H350 has a threshold of 1,000 mg/kg, and so all three samples with TBBPA at levels greater than 1,000 mg/kg detected in screening are either likely or highly likely to exceed the threshold for HP 7, carcinogenic. Since both substances are classified as H410, all four samples may exceed the hazardous threshold of 2,500 mg/kg for HP 14, ecotoxic. Table 4.21 shows the samples with classified BFRs detected during screening and the likelihood they exceed the associated hazardous thresholds.

Table 4.21 Plastic products BFR screening results (classified substances >1,000 mg/kg)

Sample	Description	XRF (mg/kg)	Screening concentration band (mg/kg)		HP threshold exceedance	
		Bromine	TBBPA	2,4,6-TBP	HP 14	HP 7
1080	Plastic casing	112,992	ND	>10,000	Highly likely	N/A
3088	Fire exit sign case	49,125	>10,000	ND	Highly likely	Highly likely
5049	Spacers	12	1,000 – 10,000	ND	Possible	Possible
5064	Trim	30	>10,000	ND	Highly likely	Highly likely

Two of the samples where TBBPA was detected had bromine levels of less than 1000 mg/kg identified during XRF scanning. XRF is a semi-quantitative surface analysis method, which may indicate the sample has a coating. Sample 5064 was found to contain over 300,000 mg/kg chlorine in XRF scanning, suggesting it is either PVC or coated with PVC, as lead was also detected above 10,000 mg/kg.

Six samples were found to contain hazardous phthalate compounds at between 1,000 and 10,000 mg/kg. All six contained an inseparable phthalate group which contains two phthalates (DEHP and DIOP) classified as H360. As H360 has a HP 10 threshold of 3,000 mg/kg these samples could potentially exceed this threshold. These samples are detailed in Table 4.22.

Table 4.22 Plastic products phthalate screening data (classified substances >1,000 mg/kg)

Sample	Description	XRF (mg/kg)	Screening concentration band (mg/kg)	HP threshold exceedance
		Chlorine	DEHP/DNOP/DIOP	HP 10
2201	Plastic seal	28,0437	1,000 – 10,000	Possible
4133	Fire extinguisher stand	397	1,000 – 10,000	Possible
5016	Trim	317,321	1,000 – 10,000	Possible
5032	Fire alarm sign	259,032	1,000 – 10,000	Possible
5035	Plastic strip	316,075	1,000 – 10,000	Possible
5044	Plastic trim	263,963	1,000 – 10,000	Possible

4.2.4. Quantitative analysis

Sample Selection

A total of eight plastic samples were selected for quantitative testing. Justification for selection is provided in Table 4.23.

Table 4.23 Plastic product sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	5/51	This selection included the three samples with BFRs identified above 10,000 mg/kg as well a sample where Deca-BDE detected above 1,000 mg/kg.
SCCPs and MCCPs	4/62	The sample where CPs were detected was selected along with some samples with a range of chlorine concentrations.
Phthalate and UV-328	3/67	Samples with a range of elevated chlorine concentrations.
PFAS	0/20	Low priority category as products unlikely to require the functionality given by PFAS.
OPFRs	1/20	Two samples where TPP was identified at <1,000 mg/kg were not selected for quantification as this is well below hazardous threshold. One sample was selected as an example from this category.

Brominated flame retardants

The results of the quantitative BFR analysis are provided in Table 4.24.

Table 4.24 Plastic product BFR quantitative results

Sample	Description	Classified (POPs) (mg/kg)	Classified (hazard statement codes) (mg/kg)		Non-Classified (mg/kg)	
		deca-BDE	2,4,6-TBP	TBBPA	TTBP-TAZ	DBDPE
1080	Plastic casing	<150	2,830	<350	22,000	2,390
3088	Fire exit sign case	<140	<360	60,800	<260	<680
3090	Cable conduit	<160	<400	<320	<280	<750
4102	Tray	11,500	<400	500	<290	<760
5064	Trim	<160	<400	12,800	<280	<750

Note: Orange shading above LOQ, red above a hazardous threshold green above POPs threshold

Of the five plastic samples selected for BFR analysis all but one (3090) were found to contain BFRs above LOQ. Sample 5064 was the only sample to contain deca-BDE above LOQ with a concentration of 11,500 mg/kg. This concentration is well above the POPs threshold for PBDEs (500 mg/kg).

Sample 1080 was found to have a 2,4,6-TBP concentration of 2,830 mg/kg. 2,4,6-TBP has several hazardous statement codes, of which only H410 is of relevance at the concentrations quantified. H410 has a hazardous threshold of 2,500 mg/kg for HP 14, which this sample exceeds.

Two samples (3088 and 5064) had a TBBPA concentration above 10,000 mg.kg. As TBBPA is classified as both H350 and H410 (most stringent) the hazardous thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg) would apply. Both samples far exceed these thresholds.

Dechlorane plus

Dechlorane plus was not detected above the LOQ of between 70 and 80 mg/kg in any of the samples analysed.

Chlorinated paraffins

The results of the quantitative CPs analysis are provided in Table 4.25. Of the four plastic samples sent for quantitative CPs analysis only the sample which had been identified in the screening (4152) as containing SCCPs between 1,000 and 10,000 mg/kg was found to have a SCCPs concentration above the LOQ. This sample contained 5,100 mg/kg SCCPs, which is below the current UK POPs threshold of 10,000 mg/kg but above a potential future threshold of 1,500 mg/kg. MCCPs were also detected in this sample at a similar concentration (4,300 mg/kg). As MCCPs are proposed for listing under the Stockholm Convention they could contribute to a CPs POPs exceedance in the future.

Table 4.25 Plastic products chlorinated paraffins quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
1080	Plastic casing	<1,000	2,100
3090	Cable conduit	<1,000	<1,000
4157	Fire extinguisher sign	<1,000	<1,000
4152	Fire signage	5,100	4,300

Note: Orange shading above LOQ, red above a hazardous threshold

Both SCCPs and MCCPs have a classification of H410 which has a HP 14 hazardous threshold of 2,500 mg/kg, this sample would therefore have a concentration above the HP 14 threshold. SCCPs are also classified as H351, with the concentration in this sample below the 10,000 mg/kg threshold for HP 7.

An additional sample which was not identified to contain any CPs in the semi-quantitative screening analysis was found to have an MCCPs concentration of 2,100 mg/kg, slightly below the associated HP 14 threshold (2,500 mg/kg). However, it is above the cut off threshold and would therefore be considered as part of the overall HP 14 assessment. Since this is a significant concentration, it would have been expected to have been detected during screening. This highlights the limitation of using only screening to identify POPs compounds.

Phthalates

The results of the phthalate analysis are provided in Table 4.26.

Table 4.26 Plastic products phthalate quantitative results

Sample	Description	Non-Classified (mg/kg)	
		DIDP	DINCH
1080	Plastic casing	5,560	6,080
4157	Fire extinguisher sign	3,160	<200
R005	Plastic skirting	1,360	<200

Note: Orange shading results above LOQ

No phthalates with hazardous classifications were detected above the LOQ. Sample R005 was identified to contain the phthalate group DEHP/DNOP/DIOP below 1,000 mg/kg during screening, however as DEHP/DIOP quantitative LOQ is 2,000 mg/kg, it may be present in this range.

All three samples were found to contain DIDP above 1,000 mg.kg however the screening analysis did not identify this substance in any of the samples. Sample 1080 was found to

have a DINCH concentration of 6,080 mg/kg. This is in line with the screening data which matches the quantification results for all three samples.

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the three plastic samples sent for quantitative analysis.

Organophosphate flame retardants

No OPFRs were identified above the LOQ, this matches the screening data. The highest LOQ was for TCPP at 240 mg/kg.

4.2.5. Summary

Evaluating the “other plastics products category” is difficult, due to the wide range of items from often unknown applications. It is therefore challenging to characterise this waste stream as a distinct category. It is entirely possible in such a broad category that items which were not available for sampling could contain substances of interest to this study.

Of the substances classified as POPs or with hazard statement codes, BFRs were the group of substances where most exceedances to thresholds were observed. One sample contained deca-BDE above the POPs threshold and SCCPs were also detected in another sample, although below the threshold.

Table 4.27 summarises the results for the quantitative analysis of the plastic products samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Scanning using XRF highlighted high levels of lead (>10,000 mg/kg) in several samples thought to be PVC (due to the presence of chlorine above10,000 mg/kg). Arsenic and antimony were also detected at significant concentrations, however in fewer samples. Table 4.28 provides a rating as to the relative prevalence of the four key elements.

Table 4.27 Summary of the prevalence of classified substances in plastic products

Substance	Relative prevalence	Commentary
deca-BDE	Medium	An exceedance of the POPs threshold for deca-BDE was observed in one sample, which contained 11,500 mg/kg.
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	This category contained the one sample with SCCPs present at 5,100 mg/kg, which is below the current POPs threshold.
MCCPs	Medium	The sample containing SCCPs also contained MCCPs at 4,300 mg/kg, with one additional sample containing 2,100 mg/kg MCCPs.
Classified BFRs	Medium	Two BFRs (2,4,6-TBP and TBBPA) were detected in three samples above thresholds for HP 7 and HP 14.
Classified phthalates	Low	
Classified OPFRs	Low	

Table 4.28 Summary of key elements in plastic products

Element	Relative prevalence	Commentary
Arsenic	Medium	Arsenic was detected at concentrations over 1,000 mg/kg in five samples, potentially resulting in a HP 7 threshold exceedance if present as arsenic trioxide.
Antimony	Medium	Antimony was detected at concentrations above 10,000 in three samples potentially resulting in a HP 7 threshold exceedance if present as antimony trioxide.
Lead	High	Lead was detected in 19 samples at concentrations above HP 10 and HP 14 thresholds for lead compounds.
Zinc	Low	

Table 4.29 shows the samples which exceeded relevant thresholds. The main exceedance of this category is due to lead concentrations. As further categories were not defined, all samples are presented.

Table 4.29 Plastic sample exceeding thresholds

Sample	Description	Samples exceeding POPs thresholds (n)		Samples exceeding hazardous property thresholds (n)				
		Quantitative		Quantitative			XRF	
		PBDEs	SCCPs	2.4.6-TBP	TBBPA	CPs (sum)	Lead	Zinc
1021	Plastic duct	-	-	-	-	-	34,242	<2
1040	Plastic guard	-	-	-	-	-	20,386	34
1080	Plastic casing	<150	<600	2,830	<350	2,100	4	10
3036	Inner electrical skirting	-	-	-	-	-	15,653	<2
3088	Fire exit sign case	<140	-	<360	60,800	-	4	<2
3095	Skirtings	-	-	-	-	-	18,068	<2
3096	Cable box	-	-	-	-	-	31,602	<2
3112	Curved plastic piece	-	-	-	-	-	22,367	<2
3114	Plastic edging	-	-	-	-	-	12,343	26
4045	Skirting	-	-	-	-	-	17,570	5
4057	Floor joint seal	-	-	-	-	-	14,572	5
4081	Plastic skirting	-	-	-	-	-	12,096	14
4102	Tray	11,500	-	<400	500	-	4	228
4127	Plastic locker lock	-	-	-	-	-	4	28,326
4133	Fire extinguisher stand	-	-	-	-	-	17,111	95
4152	Fire signage	-	5,100*	-	-		4	<2
5016	Trim	-	-	-	-	-	23,950	64
5034	Fire alarm sign	-	-	-	-	-	4	172,217
5035	Plastic strip	-	-	-	-	-	19,851	78
5044	Plastic trim	-	-	-	-	-	19,317	62
5064	Trim	<160	-	<400	12,800	-	15,017	14
5068	Cable/pipe bracket	-	-	-	-	-	25,377	40
R005	Skirting	-	-	-	-	-	25,951	3
Total:		1 (5)	1 (4)	1 (5)	2(5)	1 (4)	17 (150)	2 (150)

*Above possible future UK threshold of 1,500 mg/kg.

4.3. Pipes and ducting

4.3.1. Sample collection

A total of 118 plastic pipe and ducting samples were collected during this project. The samples collected were divided into two main categories as outlined in Table 4.30. All samples were free of visible contamination. Due to the varied nature of these samples, descriptors are used in tables to aid data interpretation.

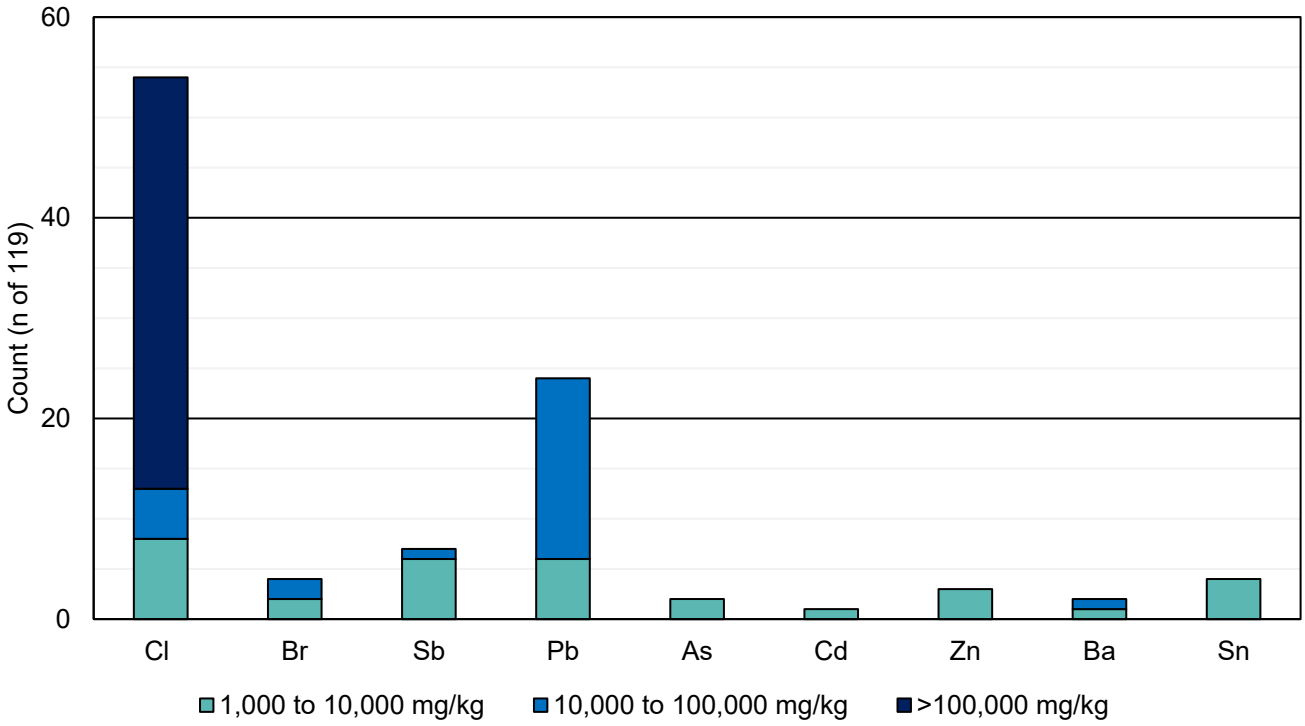
Table 4.30 Pipe and ducting categories

Category	Count	Description
Indoor pipes and ducting	71	A variety of internal plumbing pipes and well as cable and air ducting pipes.
Outdoor pipes and guttering	47	Predominantly guttering and drainpipes as well as some other external piping.

4.3.2. XRF scanning

All samples collected underwent XRF analysis scanning in triplicate. The range of target element concentrations are outlined in Figure 4.5.

Figure 4.5 Pipe and ducting XRF results



Bromine was identified above 1,000 mg/kg in four pipe and ducting samples, of which all but one sample (2007) also had a concentration of antimony above 1,000 mg/kg. The samples which had elevated bromine were all indoor pipes and ducting, as shown in

Table 4.31. Antimony was below 10,000 mg/kg in all samples and therefore below the HP 7, carcinogenic threshold.

Table 4.31 Pipe and ducting samples with bromine and antimony >1,000 mg/kg

Sample	Description	Bromine (mg/kg)	Antimony (mg/kg)
2007	Cable ducting	13,786	1,793
4025	Vent cover	12,922	6,342
4049	Cable ducting	1,918	1,314
4080	Cable duct end	1,581	<18

Four further samples contained antimony above 1,000 mg/kg, all of which also contained chlorine above 10,000 mg/kg. One of these samples contained 21,600 mg/kg antimony. Antimony is likely to be present as antimony trioxide which has a H351 classification. This sample is therefore above the H351 threshold of 10,000 mg/kg for HP 7. These samples are shown in Table 4.32.

Table 4.32 Pipe and ducting samples with antimony >1,000 mg/kg and bromine <1,000 mg/kg

Sample	Description	Antimony (mg/kg)	Chlorine (mg/kg)
4153	Indoor pipe (flexible)	21,657	34,410
4005	Indoor pipe (rigid plastic)	1,912	450,272
3110	Indoor pipe (rigid plastic)	1,315	18,012
1164	Outdoor pipe (rigid plastic)	1,169	280,999

Of the pipe and ducting samples analysed 54 (46%) had a chlorine concentration above 1,000 mg/kg, 41 of which had a concentration above 100,000 mg/kg, indicating they were made of PVC.

Lead was detected above 10,000 mg/kg in 18 samples (15%). Similarly to the general plastic category the majority (14) of these samples (77%) also contained chlorine above 100,000 mg/kg. This would suggest the majority of pipe sample with elevated lead are made from PVC.

Lead (as lead compounds) is classified as H360 and H410 and has thresholds of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. Despite the semi-quantitative nature of the handheld XRF analysis a concentration over 10,000 mg/kg would put the sample well above these hazardous thresholds. Of the samples, 24 contained lead at levels over 3,000 mg/kg and are highly likely to exceed thresholds for both HP 10 and HP 14.

4.3.3. Chemical Screening

From the available pipes and ducting samples, 21 were selected for chemical screening, retaining the proportion of these samples in the overall sample population (~11%). Both sub-categories were selected in similar proportions with slightly more indoor pipes and ducting due to their high availability in the sampled C&D waste streams. The breakdown of samples selection by category is provided in Table 4.33.

Table 4.33 Pipe and ducting sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Pipes and ducting (all)	118	21
Indoor pipes and ducting	71	12
Outdoor pipes and guttering	47	9

The selection included the four samples with elevated bromine, the three samples with elevated antimony, four samples with elevated lead and samples with a range of chlorine concentrations.

Screening results – POPs

Of the six POPs compounds included in the screening list only deca-BDE was identified. The details of the samples identified to contain these compounds are provided in Table 4.34.

Table 4.34 Pipes and ducting POPs screening results

Sample	Description	XRF (mg/kg)			Screening concentration bands (mg/kg)	
		Bromine	Antimony	Chlorine	SCCPs	Deca-BDE
4049	Cable ducting	12,922	6,342	416	ND	1,000 – 10,000
4080	Cable duct end	1,918	1,314	71	ND	<1,000

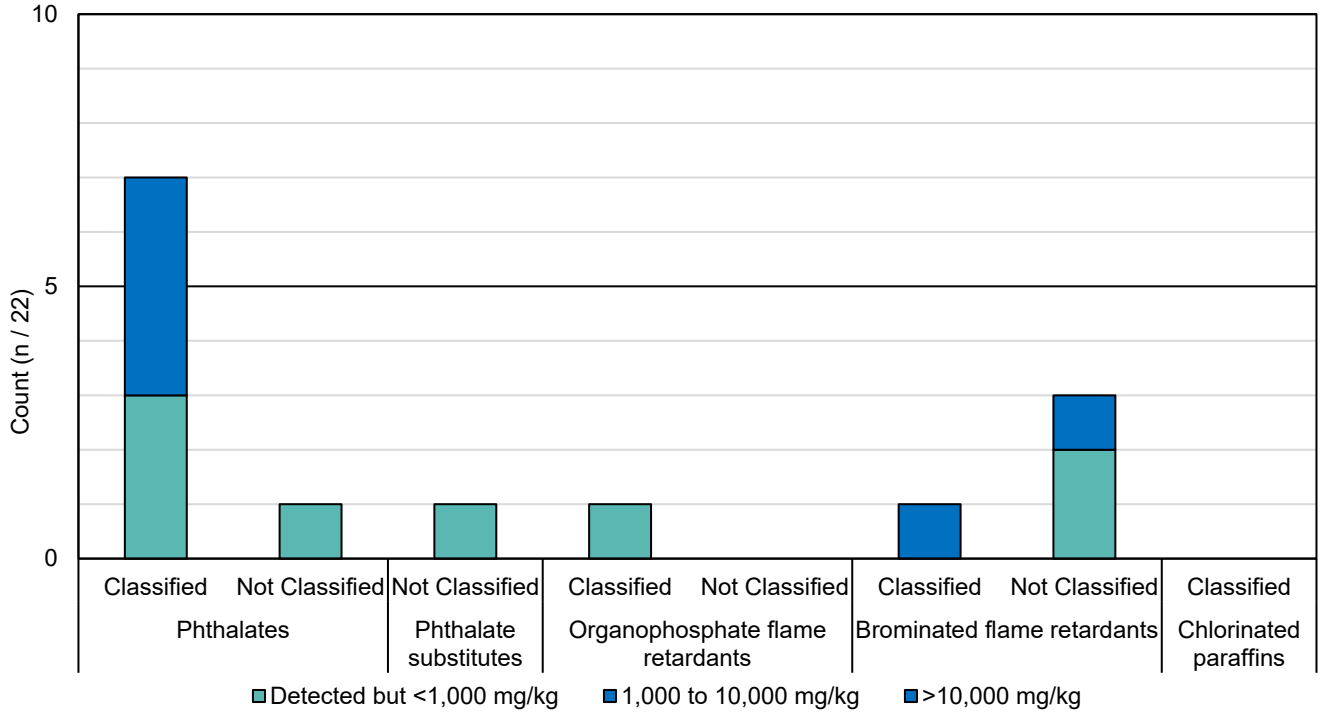
One sample (4049) was found to have a deca-BDE concentration between 1,000 and 10,000 mg/kg and one (4089) with a concentration less than 1,000 mg/kg. Both samples were from flexible ducting for cable management. As the POPs threshold for PBDEs is 500 mg/kg sample 4049 would exceed this threshold but the classification of sample 4080 remains undefined highlighting the limitations of screening for PBDE POPs classification.

No other sample was found to contain POPs or chemicals proposed for listing under the Stockholm Convention.

Screening results – classified substances

Of the 21 samples analysed eight samples had at least one hazardous substance detected. A breakdown of the compounds detect by substance category is provided in Figure 4.6.

Figure 4.6 Pipes and ducting screening results



Chlorinated paraffins were not detected in any samples of pipes above 1,000 mg/kg.

One sample (4025) was found to contain TBBPA, a hazardous BFR, above 10,000 mg/kg. As this compound has a classification of H350 and H410 this would put the TBBPA concentration of the sample above the HP thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg). This sample had the highest bromine concentration detected in the XRF analysis (13,786 mg/kg).

Three samples were found to contain a phthalate group which includes DEHP and DIOP between 1,000 and 10,000 mg/kg. DEHP and DIOP are classified as H360. As the HP 10 threshold is 3,000 mg/kg there is the potential for these samples to exceed this threshold. One of these samples also contained DIHP between 1,000 and 10,000 mg/kg which is also classified as H360. An additional sample had the hazardous phthalate BBP detected between 1,000 and 10,000 mg/kg. BBP is classified as both H360 and H410, and this sample has the potential to exceed the relevant HP 10 (3,000 mg/kg) and HP 14 (2,500 mg/kg) thresholds. Table 4.35 shows the four samples discussed above.

Table 4.35 Pipes and ducting phthalates screening results (classified substances >1,000 mg/kg)

Sample	Description	XRF (mg/kg)	Screening concentration bands (mg/kg)			HP threshold exceedance	
		Chlorine	BBP	DIHP	DEHP/ DNOP/ DIOP	HP 10	HP 14
1004	Indoor pipe (rigid plastic)	307,701	ND	ND	1,000 – 10,000	Possible	N/A
1065	Indoor pipe (rigid plastic)	63	1,000 – 10,000	ND	ND	Possible	Possible
1098	Gutter	186,722	ND	ND	1,000 – 10,000	Possible	N/A
7043	Gutter	150,512	ND	1,000 – 10,000	1,000 – 10,000	Possible	N/A

4.3.4. Quantitative analysis

Sample Selection

A total of 11 pipe and ducting samples were selected for quantitative testing. Justification for selection is provided in Table 4.36.

Table 4.36 Pipes and ducting sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	3/51	This selection included the only sample identified to contain TBBPA above 10,000 mg/kg as well as the two samples with identified deca-BDE.
SCCPs and MCCPs	2/62	Samples with elevated chlorine.
Phthalate and UV-328	6/67	This selection included a range of samples identified with elevated phthalates.
PFAS	0/20	Low priority category due to required material properties.
OPFRs	0/20	Screening did not identify any samples with >1,000 mg/kg OPFRs, and so unlikely to be present above relevant hazardous thresholds.

Brominated flame retardants

The results of the quantitative BFR analysis are provided in Table 4.37.

Table 4.37 Pipes and ducting BFR quantitative results

Sample	Description	Classified (POPs) (mg/kg)	Classified (hazard statement codes) (mg/kg)	Non-Classified (mg/kg)
		Deca-BDE	TBBPA	TBBPA-BDBPE
4025	Vent cover	<150	107,600	<160
4049	Cable ducting	3,950	<330	31,900
4080	Cable duct end	1,200	<290	10,400

Note: Orange shading above LOQ, red above hazardous threshold, green above POPs threshold

Of the three pipe samples analysed two (4049 and 4080) were found to contain deca-BDE. Both samples had a concentration well above the POPs threshold of 500 mg/kg.

A single sample was identified to contain TBBPA above LOQ with a concentration of 107,600 mg/kg (>10%). As TBBPA is classified as both H350 and H410 (most stringent) the hazardous thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg) would apply. This sample would far exceed these thresholds.

Dechlorane Plus

Dechlorane plus was not detected above the LOQ of between 70 and 80 mg/kg in any of the samples analysed.

Chlorinated paraffins

The results of the quantitative CPs analysis are provided in Table 4.38. Of the two pipe and ducting samples sent for quantitative CP analysis neither were identified to contain SCCPs above the LOQ.

Table 4.38 Pipes and ducting chlorinated paraffins quantitative results

Sample	Description	SCCPs(mg/kg)	MCCPs (mg/kg)
2032	Outdoor pipe (rigid plastic)	<600	<600
7035	Outdoor pipe (rigid plastic)	<600	10,400

Note: Red shading above a hazardous threshold

In Sample 7035 MCCPs were identified above 10,000 mg/kg. As this compound is proposed for listing under the Stockholm Convention, it could impact the sample's POPs classification in the future. MCCPs are classified as H410 which has a HP 14 hazardous threshold of 2,500 mg/kg. Based on the MCCPs concentration this sample would exceed this hazardous threshold.

The MCCPs concentration for 7035 was not identified in the screening analysis despite being quantified at over 10,000 mg/kg. This highlights the limitations of the screening analysis for CPs quantification as it did not detect the hazardous exceedance or possible future POPs exceedance.

Phthalates

The results of the phthalate analysis are provided in Table 4.39.

Table 4.39 Pipes and ducting phthalate quantitative results

Sample	Description	Classified (hazard statement codes) (mg/kg)	Not classified (mg/kg)			
		DEHP/DIOP	DNOP	DIDP	DINCH	DEHA
1004	Indoor pipe (rigid plastic)	7,050	2,230	5,270	<200	59,460
1030	Gutter	<270	<60	2,580	<200	<1900
1065	Indoor pipe (rigid plastic)	<2,200	<40	1,700	<200	<1500
1098	Gutter	<1,700	<40	2,630	2,030	<1200
3110	Indoor pipe (rigid plastic)	<2,200	<50	1,940	<200	<1500
R002	Gutter	<2,200	<50	2,670	<200	<1500

Note: Orange shading results above LOQ, red shading above a hazardous threshold

A single sample (1004) was identified to contain the phthalate group DEHP/DIOP at a concentration of 7,050 mg/kg. These phthalates could not be distinguished during quantitative analysis; however, both are classified as H360. This classification has an individual substance threshold for HP 10 of 3,000 mg/kg, and so this sample exceeds the threshold regardless of which is present.

Sample 1098 was also identified to have a DEHP/DNOP/DIOP concentration in the middle screening concentration band but none of the compounds were identified above LOQ. This however does not contradict the screening analysis as the LOQ of DEHP/DIOP is above 1,000 mg/kg due to required diluting in the analytical approach (as outlined in Section 6).

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the six pipe samples sent for quantitative analysis.

4.3.5. Summary

Relatively low levels of target substances were identified in waste pipes and ducting during the chemical screening analysis, which resulted in a low number of samples being sent for

quantitative analysis. However, two samples were quantified with concentrations of deca-BDE over the POPs threshold of 500 mg/kg, which were categorised as cable ducting. A third sample, recorded as a vent cover, had high levels of TBBPA. Aside from these BFRs, one sample contained MCCPs above hazardous thresholds for HP 14, and one sample contained phthalates above hazardous thresholds for HP 10.

Table 4.40 summarises the results for the quantitative analysis of pipe samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Table 4.40 Summary of the prevalence of classified substances in pipes and ducting

Substance	Relative prevalence	Commentary
deca-BDE	High	An exceedance of the POPs threshold for deca-BDE was observed in two samples.
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Low	
MCCPs	Medium	One sample contained MCCPs at a concentration over 100,000 mg/kg.
Classified BFRs	Medium	One sample contained TBBPA at a concentration over 100,000 mg/kg.
Classified phthalates	Low	
Classified OPFRs	Low	

Scanning using XRF highlighted high levels of lead (>10,000 mg/kg) in a number of samples thought to be PVC (due to chlorine present above10,000 mg/kg) with 20% of samples in this category exceeding the HP 14 threshold of 2,500 mg/kg. Arsenic and antimony were also detected at significant concentrations but in significantly fewer samples, indicating these substances are not prevalent. Table 4.41 provides a rating as to the relative prevalence of the four key elements.

Table 4.41 Summary of key elements in pipes and ducting

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	High	Lead was detected in 19 samples at concentrations above HP 10 and HP 14 thresholds for lead compounds.
Zinc	Low	

Table 4.42 shows the number of samples which exceeded relevant thresholds for indoor and outdoor pipes. Although the categorisation is subjective, and difficult to carry out on waste of unknown origin, it suggests indoor pipes may be more likely to contain PBDEs, and outdoor more likely to contain lead in concentrations exceeding the relevant hazardous property threshold.

Table 4.42 Pipe samples exceeding thresholds by category

Category	Total collected (n)	Samples exceeding POPs thresholds (n)		Samples exceeding hazardous property thresholds (n)			
		Quantitative		Quantitative			XRF
		PBDEs	SCCPs	TBBPA	CPs	DEHP/ DIOP	Lead
Pipes and ducting (all)	118	2 (3)	0 (2)	(3)	1 (2)	1 (6)	18
Indoor pipes and ducting	71	2 (3)	-	1(3)	-	1 (3)	7
Outdoor pipes and guttering	47	-	0 (2)	-	1 (2)	0 (3)	11

4.4. Flooring

4.4.1. Sample collection

In total 85 flooring samples were collected from C&D waste. These samples were divided into six categories as outlined in Table 4.43.

Table 4.43 Flooring sub-categories

Category	Count	Description
Vinyl/Laminated	34	Flexible or semi-flexible polymer-based flooring materials
Carpet tiles	24	Sections of tiled carpet normally commonly with a thick rubber backing
Rubber	6	Rubberised flooring/matting
Underfloor sheeting	9	Barrier membranes and other sub-floor backings (excluding foam)
Underfloor foam	9	Insulating sub-floor layers (e.g. underlay)
Other flooring	3	Other flooring items which did not fit the outlined categories above (e.g. supports)

4.4.2. XRF scanning

All samples collected underwent XRF analysis in triplicate. The range of target element concentrations recorded in the insulation category are outlined in Figure 4.7.

Bromine was identified at a concentration above 1,000 mg/kg in a single sample (R008 – underlay) at 1,242 mg/kg. This sample had an antimony concentration of 753 mg/kg.

All six samples with an antimony concentration above 1,000 mg/kg also had a chlorine concentration above 1,000 mg/kg, with four samples likely to be PVC where the chlorine levels were greater than 100,000 mg/kg. Antimony was below 10,000 mg/kg in all samples, so they are unlikely to contain antimony trioxide above the H351 threshold of 10,000 mg/kg for HP 7 carcinogenic. These samples are shown in Table 4.44.

Figure 4.7 Flooring XRF results

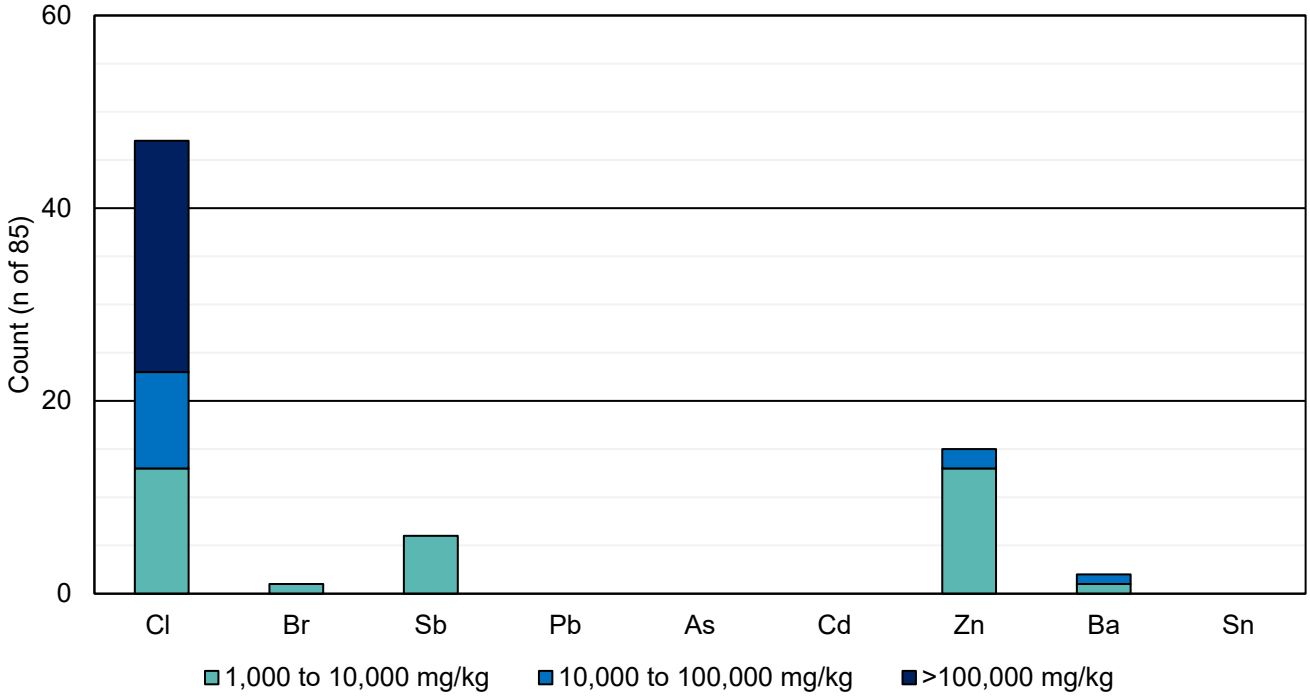


Table 4.44 Flooring samples with >1,000 mg/kg antimony

Sample	Category	Antimony (mg/kg)	Chlorine (mg/kg)
3098	Vinyl/Laminated	7,405	264,665
3033	Vinyl/Laminated	7,245	3,401
3068	Vinyl/Laminated	6,272	3,118
3105	Vinyl/Laminated	6,209	310,586
5015	Vinyl/Laminated	2,672	155,869
N7	Vinyl/Laminated	2,180	271,619

Of the flooring samples collected 47 (55%) had a chlorine concentration over 1,000 mg/kg of which 24 had a concentration above 100,000 mg/kg suggesting they are PVC, a common polymer used for resilient flooring.

No samples contained lead above 1,000 mg/kg, despite several samples likely being PVC. Europe has a strong vinyl flooring manufacturing industry, and its likely products used have been produced in the UK or EU where lead stabilisers have been phased out. This, combined with a potential shorter lifespan for flooring compared with rigid PVC products due to high levels of wear, suggests lead is not prevalent in this waste stream due to replacement timeframes.

Zinc was identified above 1,000 mg/kg in 15 flooring samples, two of which contained zinc above 10,000 mg/kg. These samples were a mix of vinyl, underfloor and rubber matting. Zinc is likely present as a filler material in rubberised components or as a blowing agent in

expanded vinyl flooring and underlay. Assessing hazardous properties is challenging due to the range of zinc compounds, however, using a worst-case compound of zinc oxide (H410), seven samples would exceed the 2,500 mg/kg threshold and lead to an HP 14, ecotoxic classification.

4.4.3. Chemical Screening

Sample selection

From the flooring category, 11 samples were selected for chemical screening, which represents a slight reduction in the representation of this product compared with the samples collected (flooring represented 8% of all samples taken but 6% of all samples sent for chemical screening). This is because vinyl flooring samples were readily available at several of the sampling locations and some flooring types were not a high priority for further testing due to previous work undertaken by WRc on behalf of Natural Resource Wales (POPs in carpets). The breakdown of sample selection by category is provided in Table 4.45.

Table 4.45 Flooring sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Flooring (all)	85	11
Vinyl/Laminated	34	7
Carpet tiles	24	1
Rubber	6	1
Underfloor sheeting	9	2
Underfloor foam	9	0
Other flooring	3	0

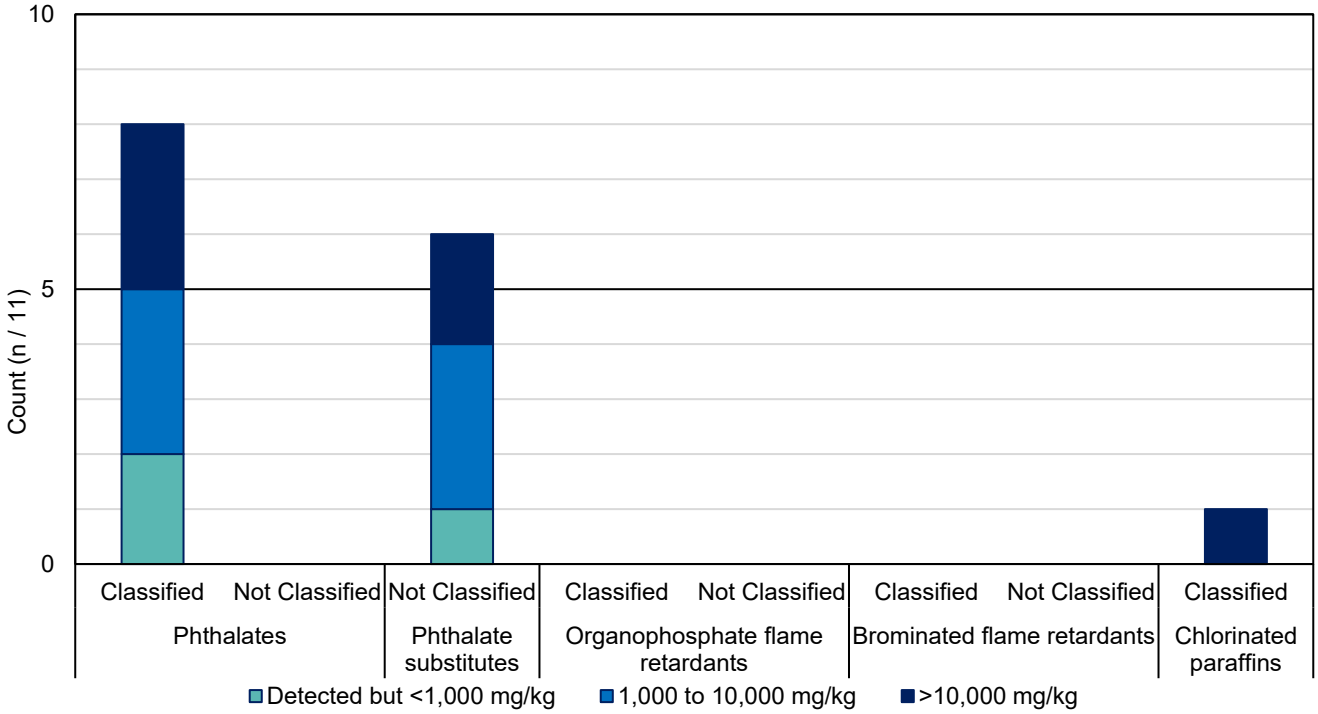
Screening results - POPs

Of the six POPs compounds included in the screening list none were detected in the flooring samples.

Screening results – classified substances

Of the 11 samples sent for screening, eight were identified to contain a substance with a hazardous classification. A breakdown of the compounds detect by hazardous classification is provided in Figure 4.8.

Figure 4.8 Flooring screening results



MCCPs are classified as H410 which has a HP threshold of 2,500 mg/kg for HP 14. The sample identified to contain MCCPs above 10,000 mg/kg would therefore exceed this threshold. This sample also contained BBP above 10,000 mg/kg, a phthalate with hazard statement codes H360, H400 and H410, meaning it is likely to exceed the 3,000 mg/kg threshold for HP 10 and the 2,500 mg/kg threshold for HP 14. Therefore, this sample is highly likely to be hazardous by HP 10 and HP 14. As MCCPs are also recommended for listing under the Stockholm Convention they could contribute to a CPs POPs exceedance of this sample in the future.

Six samples were found a range of classified phthalates, as shown in Table 4.46. In some cases, classified and non-classified phthalates have been grouped due to difficulties in distinguishing each substance during screening, and it is therefore difficult to assess the hazard status. All phthalates/groups have H360 hazard statement codes with a 3,000 mg/kg threshold for HP 10, toxic for reproduction. BBP has the additional H400 and H410 hazard statement codes and a corresponding threshold of 2,500 mg/kg for HP 14, ecotoxic.

No organophosphate or brominated flame retardants were detected at any concentration in any sample in this category.

Table 4.46 Flooring phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration bands (mg/kg)				HP threshold exceedance	
		Chlorine	BBP	DINP/ DHUNP	DIHP	DEHP/ DNOP/ DIOP	HP 10	HP 14
1044	Vinyl/ Laminated	200,542	ND	1,000 – 10,000	ND	ND	Possible	N/A
2179	Underfloor sheeting	95,765	>10,000	ND	1,000 – 10,000	ND	Highly likely	Highly likely
3105	Vinyl/ Laminated	310,587	ND	1,000 – 10,000	ND	1,000 – 10,000	Possible	N/A
5015	Vinyl/ Laminated	155,869	ND	1,000 – 10,000	1,000 – 10,000	>10,000	Likely*	N/A
R047	Vinyl/ Laminated	180,737	ND	ND	1,000 – 10,000	1,000 – 10,000	Possible	N/A
R051	Vinyl/ Laminated	245,278	ND	>10,000	ND	>10,000	Likely*	N/A

*It is not possible to conclude a 'highly likely' category since the phthalate present may be the un-classified substance in the group.

4.4.4. Quantitative analysis

Sample Selection

All 11 samples selected screening also were selected least one analysis suite. Justification for selection is provided in Table 4.47.

Table 4.47 Flooring sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	0/51	No BFRs detected and not identified as a likely source.
SCCPs and MCCPs	4/62	The samples where CPs were detected were selected along with three samples with elevated chlorine and antimony.
Phthalate and UV-328	9/67	Category identified as likely source due to use in PVC flooring to improve durability. A range of sample selected with different concentrations of different phthalates including all compounds with possible exceedances. UV-328 was not used as a factor in selection.
PFAS	2/20	Carpet tile was selected as PFAS are potentially present for stain resistance and underfloor sheeting selected for potential moisture resistance.
OPFRs	0/20	No OPFRs detected and not identified as likely source.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.48.

Table 4.48 Flooring chlorinated paraffin quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
3105	Vinyl/Laminated	<600	1,500
2179	Underfloor sheeting	<600	46,000
5015	Vinyl/Laminated	2,900	<600
N7	Vinyl/Laminated	<700	<700

Note: Red shading above a hazardous threshold

Of the four samples sent for quantitative CPs analysis a single sample (5015) was found to have an SCCPs concentration of 2,900 mg/kg. This is below the current POPs threshold for SCCPs of 10,000 mg/kg but above a potential future threshold of 1,500 mg/kg. SCCPs have a classification of H410 which has a HP 14 hazardous threshold of 2,500 mg/kg. This sample would therefore have a SCCPs concentration that exceeds this hazardous threshold. Screening did not indicate any CPs in this sample, showing the limitation of this approach for SCCPs.

MCCPs were detected at 46,000 mg/kg in sample 2179, which was reported to have a concentration greater than 10,000 mg/kg from the screening test. As MCCPs are recommended by the UK for addition to the Stockholm Convention, this sample may exceed a future POPs threshold. The concentration of MCCPs exceeds the H410 threshold for HP 14.

MCCPs were detected in one other sample (3105) at 1,500 mg/kg. This is below the HP 14 hazardous threshold but above the contribution threshold (1,000 mg/kg), and so the concentration would be added to other compounds with relevant statement codes. MCCPs were not detected during screening in this sample.

Phthalates

The results of the phthalate analysis are provided in Table 4.49.

Table 4.49 Flooring phthalate quantitative results

Sample	Description	Classified (hazard statement codes) (mg/kg)		Not classified (mg/kg)				
		BBP	DEHP/ DIOP	DINP	DIDP	DINCH	ATBC	DEHA
1044	Vinyl	<40	<2,000	<600	71,340	101,270	<2,100	<1,400
3105	Laminated	<50	<2,300	<700	15,990	<200	<2,500	<1,600
2155	Laminated	<60	<2,700	<800	1,500	<200	30,050	<1,900
2179	Backing	13,640	<2,200	<700	<1,000	<200	<2,400	21,410
5015	Vinyl	<40	46,950	<600	5,590	<200	<2,200	<1,400
N7	Vinyl	<50	<2,500	<800	3,730	<200	<2,700	<1,700
R008	Underlay	<40	<2,000	<600	<730	<200	<2,100	<1,400
R047	Vinyl	<40	<1,800	<600	<700	<200	<2,000	<1,300
R051	Vinyl	<50	20,370	44,220	<900	<200	<2,500	<1,600

Note: Orange shading results above LOQ, red shading above a hazardous threshold

Of the samples analysed, one was found to contain BBP above LOQ with a concentration of 13,640 mg/kg. As BBP is classified as both H360 and H410 it has the hazardous thresholds for HP 10 and HP 14 of 3,000 mg/g and 2,500 mg/kg respectively. This sample would therefore exceed both these thresholds.

Additionally, two samples (5015 and R051) were found to contain the DEHP/DIOP phthalate group with a hazardous classification of H360 (for both compounds) at a concentration above 20,000 mg/kg. As H360 has a HP 10 hazardous threshold of 3,000 mg/kg these samples would exceed this threshold regardless of which compound is present.

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the nine flooring samples sent for quantitative analysis.

PFAS

Of the two samples sent for PFAS analysis neither was found to contain a single PFAS substance above the LOQ of 5 µg/kg.

Polychlorinated Biphenyls (PCBs)

Of the 25 samples selected for PCB analysis three vinyl/laminated flooring samples were selected. Samples were chosen due to the flexible hard-wearing properties of vinyl flooring as well as the adhesive properties of the backing material. The results of the analysis are provided below in Table 4.50.

Table 4.50 Flooring PCBs quantitative analysis results

Sample	Category	Sum of total PCB (mg/kg)	Sum of ICES6 (mg/kg)	Sum of dl-PCB (mg/kg)	dl-PCB WHO 2005 TEQ (ng/kg)	dl-PCB WHO 2022 TEQ (ng/kg)
R046	Vinyl/Laminated	0.98	0.35	0.02	3.10	3.55
R047	Vinyl/Laminated	0.99	0.31	0.04	3.36	7.27
R048	Vinyl/Laminated	1.04	0.30	0.06	5.49	7.33

Note: Orange shading >1 mg/kg.

All samples were shown to be well below the POPs threshold of 50 mg/kg for total PCB content. One sample had a total PCB concentration above 1 mg/kg. All other samples contained 1 mg/kg or less.

The dioxin like PCB (dl-PCB) concentration was also very low in all samples. The highest concentration measured was 0.06 mg/kg, which was in the same sample that had the greatest total PCB concentration. When scaled using the WHO 2005 TEFs, the TEQ value for all samples was well below the EU POPs threshold of 5 µg/kg (5,000 ng/kg) with the highest upper bound value measured being 0.0055 mg/kg (5.49 ng/kg).

When the WHO 2022 TEFs are used to calculate the TEQ, the value increases for all samples, primarily due to the concentration of PCB 81, where the TEF has increased from 0.0003 to 0.006. The TEQs are still well below the 5 µg/kg EU limit.

The analysis by MSS demonstrated high recovery rates for the spiked samples. The average recovery observed for the dl-PCBs was 89% (+/-2%), and for the ICES6 was 80% (+/-3%).

4.4.5. Summary

The chemical screening highlighted potential threshold exceedances for CPs and phthalates, and these samples were submitted for quantitative analysis. SCCPs were found to be present in one sample of vinyl flooring below the current POPs threshold of 10,000 mg/kg, but above a potential future threshold of 1,500 mg/kg. The sample did however exceed the HP 7 and HP 14 thresholds for the associated hazard statement codes. A second sample was found to contain MCCPs exceeding the H410 threshold of 2,500 mg/kg for HP 14. This is a relatively low, but notable, level of exceedances compared to other categories with CPs present.

Phthalates, known to be present in vinyl flooring were quantified in three samples above HP 10 thresholds for the associated hazard statement codes, with one of these also above the HP 14 threshold due to BBP concentrations. DIDP, which is not classified with any hazard statement codes, was the most prevalent plasticiser. Due to their widespread use, classified plasticisers were expected to be more prevalent, however, due to the lifespan of these products, many were likely manufactured after restrictions were introduced.

Table 4.51 summarises the results for the quantitative analysis of waste flooring samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Scanning using XRF highlighted concentrations of zinc above the H410 threshold of 2,500 mg/kg for zinc oxide in seven samples, however lead was not found at concentrations exceeding HP thresholds in any sample. Table 4.52 provides a rating as to the relative prevalence of the four key elements.

Table 4.53 shows the number of samples which exceeded relevant thresholds for the various categories of flooring. The category with the most exceedances is vinyl/laminated flooring, due partly to phthalates but also zinc concentrations.

Table 4.51 Summary of the prevalence of classified substances in flooring

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	One sample of vinyl flooring was found to contain SCCPs below the current 10,000 mg/kg POPs threshold but above a potential future 1,500 mg/kg threshold.
MCCPs	Medium	Two samples contained MCCPs, although only one at concentrations exceeding a hazardous property threshold.
Classified BFRs	Low	
Classified phthalates	Medium	Despite the significant use of phthalates in vinyl flooring, only three samples were found to contain a classified phthalate in concentrations exceeding relevant hazardous property thresholds.
Classified OPFRs	Low	

Table 4.52 Summary of key elements in flooring

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	Low	
Zinc	Medium	Zinc, assumed to be present as zinc oxide, was detected in seven samples at concentrations above the HP 14 threshold.

Table 4.53 shows the number of samples within each category where exceedances in threshold limits were observed. Exceedances were primarily in the vinyl/laminated category of flooring.

Table 4.53 Flooring samples exceeding thresholds by category

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)			
		Quantitative	Quantitative			XRF
		SCCPs	CPs	BBP	DEHP/ DIOP	Zinc
Flooring (all)	85	0 (4)	2 (4)	1 (9)	2 (9)	7
Vinyl/Laminated	34	0* (3)	1 (3)	0 (7)	2 (7)	4
Carpet tile	24	-	-	-		0
Rubber	6	-	-	-		1
Underfloor sheeting	9	0 (1)	1 (1)	1 (2)	0 (2)	1
Underfloor foam	9	-	-	-	-	1
Other flooring	3	-	-	-	-	0

*One sample above possible future UK threshold of 1,500 mg/kg.

4.5. Doors and window frames

4.5.1. Sample collection

A total of 78 door and window frame samples were collected during sampling. Most samples collected consisted of white UPVC plastic samples, but a number of components (i.e. trims and draught excluders) were also collected. Table 4.54 shows a breakdown of the samples collected.

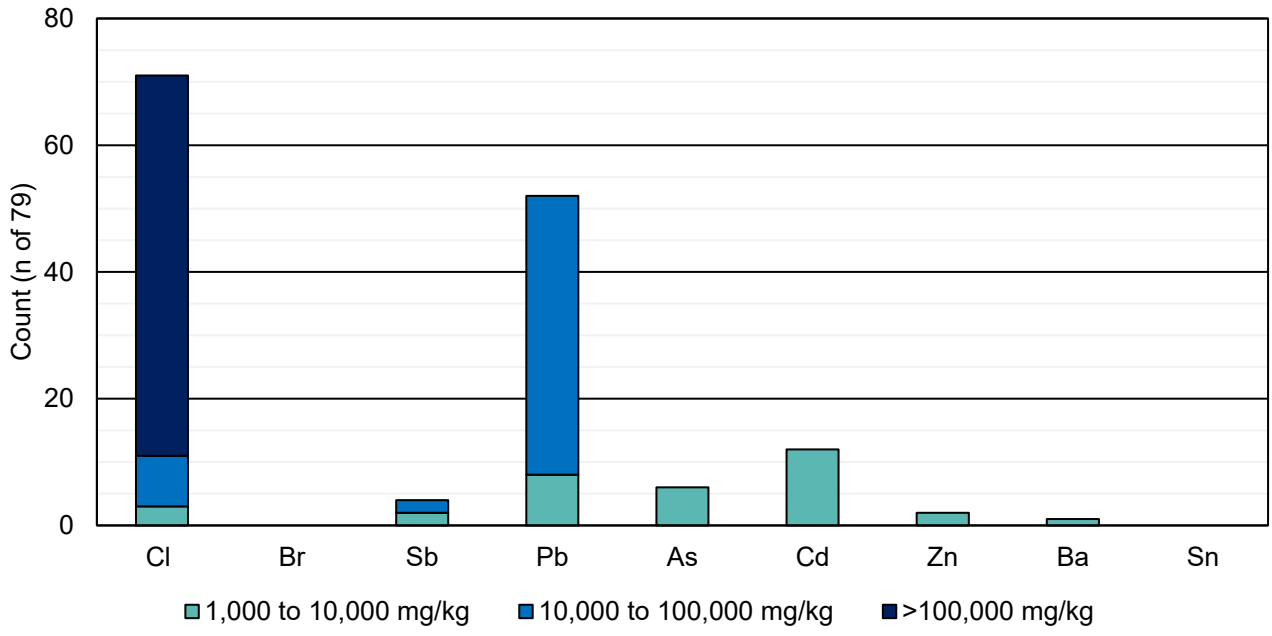
Table 4.54 Doors and window frames categories

Category	Count	Description
PVC frames	51	Plastic door and windows frames with elevated chlorine.
PVC fittings/trims	11	Plastic door and windows surrounding components other than frames with elevated chlorine (e.g. surrounds and trim).
PVC sills	6	Plastic windowsills with elevated chlorine.
Other door and window frames	10	Plastic door and window frame components without elevated chlorine or other material (e.g. draft excluders).

4.5.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded in the adhesive and sealant category are outlined in Figure 4.9.

Figure 4.9 Doors and window frames XRF results



No samples were found to contain bromine above 1000 mg/kg, with all samples containing less than 150 mg/kg.

Four samples had an antimony concentration above 1,000 mg/kg, two of which had a concentration above 10,000 mg/kg. The two samples with antimony above 10,000 mg/kg had chlorine levels below 100,000 mg/kg suggesting they may not be PVC. As antimony may be present as antimony trioxide, which is classified as H351, these two samples may be above the 10,000 mg/kg threshold for HP 7, carcinogenic. All four samples with antimony greater than 1,000 mg/kg had low lead levels. Table 4.55 provides the test data for the samples discussed above.

Table 4.55 Doors and window frames with antimony >1,000 mg/kg

Sample	Category	Antimony (mg/kg)	Chlorine (mg/kg)	Lead (mg/kg)
5003	Other doors and window frames	27,418	55,100	119
5012	Other doors and window frames	10,648	2,424	4
2117	PVC frames	1,395	64,218	4
2121	PVC sills	1,294	134,857	4

All but eight samples had chlorine concentrations above 1,000 mg/kg. These eight samples were not the primary window or door product, but rather ancillary components such as draft excluders and attachments.

Of the doors and window frames collected 59 (76%) had a chlorine concentration above 100,000 mg/kg which is to be expected for PVC based material.

The concentration of lead was above 1,000 mg/kg in 52 samples (67%) and above 10,000 mg/kg in 44 samples (56%). Lead has been used as a stabiliser in PVC formulations, and although the use of lead in new PVC formulations was voluntarily phased out by EU manufacturers by 2015, it still appears to be prevalent at high concentrations in this waste stream. This may be a result of the age of the material, but also the use of recycled PVC containing lead, or products manufactured outside the EU.

Lead (as lead compounds) is classified as H360 and H410 which have a threshold of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. All 52 samples with lead above 1,000 mg/kg contained lead concentrations above both HP 10, toxic for reproduction, and HP 14, ecotoxic thresholds, meaning 67% of samples taken in this study would be classified as hazardous.

Six of these samples also contained arsenic above 1,000 mg/kg (but less than 2,000 mg/kg). Using the worst-case compound of arsenic trioxide which has hazardous statement codes H300, H350 and H360[8], these six samples would exceed the 1,000 mg/kg H350 threshold for HP 7.

[8] H360 is not a harmonised entry but does have a number of joint entries.

4.5.3. Chemical Screening

Sample selection

A total of 22 door and window samples were selected for chemical screening resulting in slight over representation of this product (windows and doors represented 8% of all samples taken but 11% of all samples sent for chemical screening). The main justification for this was the specific interest in UV-328. UV-328 is an additive used reduce the deterioration of plastics from ultraviolet (UV) light and is believed to have been used in windows and doors, possibly as a coating. UV-328 was added to Annex A of the Stockholm Convention in 2023 and is therefore listed as a POP. The breakdown of sample selection by category is provided in Table 4.56.

Table 4.56 Door and window frames sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Doors and window frames (all)	78	22
PVC frames	51	14
PVC fittings/trims	11	3
PVC sills	6	1
Other doors and window frames	10	4

Screening results – POPs

Of the six POPs compounds included in the screening list only SCCPs were detected. Table 4.57 outlines the details of the sample.

Table 4.57 Doors and window frames POPs screening results

Sample	Category	XRF analysis (mg/kg)			Screening concentration band (mg/kg)
		Bromine	Antimony	Chlorine	SCCPs
5012	Other doors and window frames	13	10,648	2,424	1,000 – 10,000

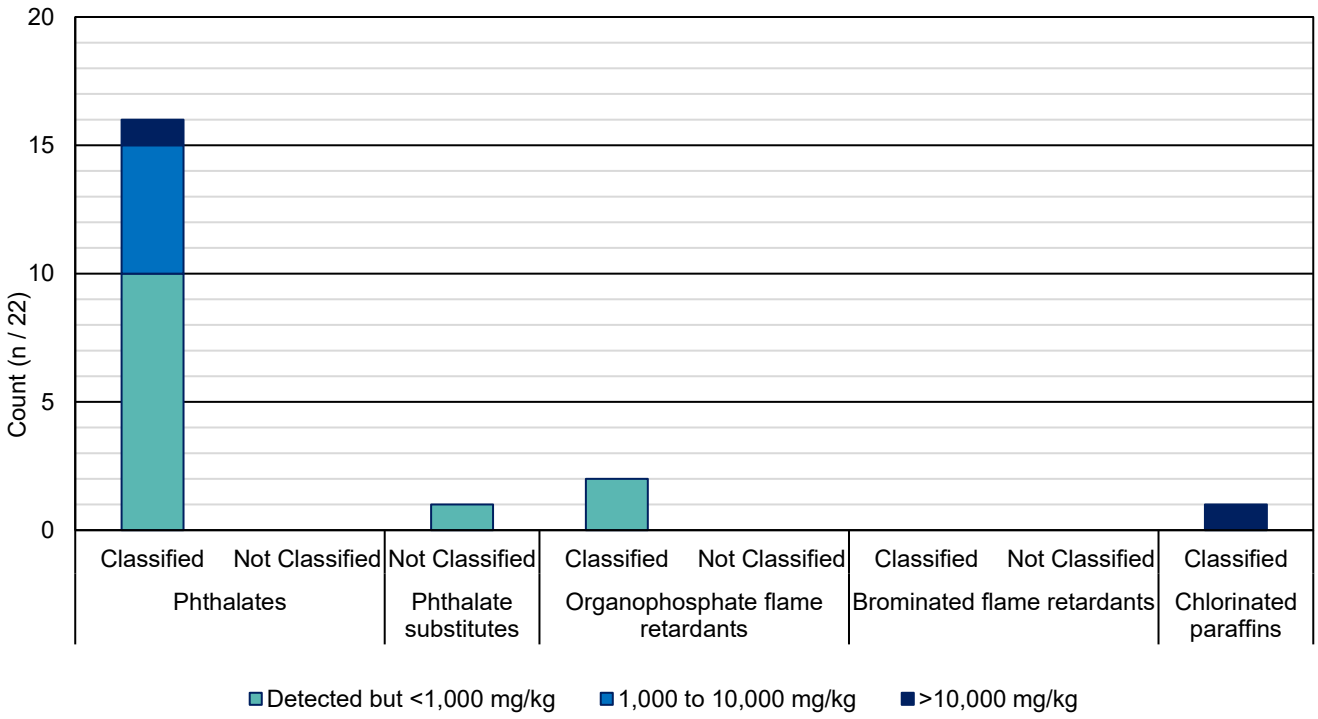
Sample 5012 was a strip of plastic trim for a door but was not identified to be PVC due to it having relatively low chlorine content. As the concentration of SCCPs was found to be between 1,000 and 10,000 mg/kg, this sample would likely not exceed the POPs threshold of 10,000 mg/kg but may be above a future POPs threshold of 1,500 mg/kg. MCCPs were also found in this sample above 10,000 mg/kg. As MCCPs are proposed for listing under the Stockholm Convention they could contribute to a CPs POPs exceedance of this sample in the future.

No other sample was found to contain POPs or other substances proposed for listing under the Stockholm Convention.

Screening results – classified substances

Of the 22 samples analysed, substances classified with hazard statement codes were detected in 14 samples. A breakdown of the compounds detect by hazardous classification is provided in Figure 4.10.

Figure 4.10 Doors and window frames screening results



MCCPs have the classification H410 which has a threshold of 2,500 mg/kg for HP 14. The sample identified to contain MCCPs above 10,000 mg/kg would therefore likely exceed this hazardous threshold. Since MCCPs are also proposed for listing under the Stockholm Convention, it may exceed a future POPs threshold for this substance.

Classified phthalates were detected in six samples above 1,000 mg/kg, as shown in Table 4.58. Five of these samples had a phthalate group including DEHP and DIOP which both have the H360 hazard statement code. Four of the five samples had levels at between 1,000 and 10,000 mg/kg meaning they possibly exceed the 3,000 mg/kg threshold for HP 10, and one sample contained over 10,000 mg/kg making it likely it exceeds the threshold and would be hazardous with HP 10. Another sample had a phthalate group with DHUNP detected at between 1,000 and 10,000 mg/kg and would therefore also possibly exceed the threshold for HP 10.

Table 4.58 Door and window frame phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration band (mg/kg)		HP threshold exceedance
		Chlorine	DINP/ DHUNP	DEHP/DNOP/DIOP	HP 10
2012	PVC frames	308,122	ND	1,000 – 10,000	Possible
2108	PVC frames	208,679	ND	1,000 – 10,000	Possible
2124	PVC frames	231,603	ND	1,000 – 10,000	Possible
5003	Other doors and window frames	55,100	1,000 – 10,000	ND	Possible
5012	Other doors and window frames	2,423	ND	>10,000	Likely*
7022	PVC frames	115,458	ND	1,000 – 10,000	Possible

4.5.4. Quantitative analysis

Sample Selection

All 22 samples selected for screening all were selected for UV-328 analysis as well as some samples for CPs. Justification for selection is provided in Table 4.59.

Table 4.59 Doors and window frames sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	0/51	No BFRs detected and not identified as likely source.
SCCPs and MCCPs	6/62	The samples where CPs were detected were selected along with three samples with elevated chlorine plus antimony or lead.
Phthalate and UV-328	22/67	Potential for this category to contain UV-328 as these products would benefit from UV protection.
PFAS	0/20	Not identified as a likely source and due to limited capacity none were selected.
OPFRs	0/20	Screening did not identify any samples with >1,000 mg/kg OPFRs, so they are unlikely to be present above relevant hazardous thresholds.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.60.

Table 4.60 Doors and window frames chlorinated paraffin quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
1201	PVC frames	<600	1,600
2107	PVC frames	1,600	<600
5003	Other doors and window frames	<600	<600
5012	Other doors and window frames	5,200	27,550
2108	PVC frames	<600	<600
2124	PVC frames	<600	<600

Note: Orange shading above LOQ, red shading above a hazardous threshold

Of the six samples sent for the quantitative CP analysis, two were found to contain SCCPs above the LOQ. The first sample (5012) was found to have a concentration of 5,200 mg/kg. This concentration is below the current POPs threshold for SCCPs of 10,000 mg/kg but above a potential future threshold of 1,500 mg/kg. This sample also contained MCCPs at a concentration of 27,550 mg/kg. As MCCPs are proposed for listing under the Stockholm Convention by the UK, it may result in a future POPs threshold exceedance. As both CPs have a classification of H410 which has a HP 14 threshold of 2,500 mg/kg, this sample would exceed this hazardous threshold.

The other sample identified to contain SCCPs had a concentration of 1,600 mg/kg, below the current 10,000 mg/kg threshold by above a potential future POPs threshold of 1,500 mg/kg. Sample 1201 was found to contain MCCPs at 1,600 mg/kg. Depending on future MCCPs POPs threshold, this sample is also at risk of a future POPs classification. CPs in both samples were above the cut off threshold of 1,000 mg/kg for inclusion in the HP 14 assessment.

Phthalates

The results of the phthalate analysis are provided in Table 4.61. Two samples were found to contain the DEHP/DIOP phthalate group above a concentration of 7,000 mg/kg. As both substances in this group are classified as H360, with a HP 10 hazardous threshold of 3,000 mg/kg, both samples would exceed this threshold regardless of which substance is present.

Table 4.61 Doors and window frame phthalate quantitative results

Sample	Category	Classified (hazard statement codes) (mg/kg)	Not classified (mg/kg)		
		DEHP/DIOP	DIDP	DINCH	DEHA
1201	PVC frames	<970	<760	<280	<1,020
1207	PVC fitting/trims	<970	<760	<280	<1,020
1212	PVC fitting/trims	<2,100	<900	<200	<1,500
2030	PVC frames	<1,000	<820	<300	<1,100
2035	PVC frames	<1,270	<1,040	<380	<1,400
2051	Other doors and window frames	<980	<800	<300	<1,080
2107	PVC frames	7,360	<820	<200	<1,500
2128	PVC frames	<2,200	<820	<200	<1,500
2006	PVC frames	<810	<660	<240	<890
2024	PVC frames	<1,620	<1,320	<490	<1,780
4096	Other doors and window frames	<970	<790	1,180	<1,070
5003	Other doors and window frames	<2,200	96,560	<200	13,040
5012	Other doors and window frames	35,900	<730	1,560	<990
R004	PVC frames	<930	<760	<280	<1,020
R022	PVC fittings/trims	<1,060	<860	<320	<1,160
R024	PVC frames	<1,140	<930	<350	<1,250
2012	PVC frames	<1,080	<880	1,730	<1,180
2108	PVC frames	<2,300	1,820	<200	<1,600
2121	PVC sills	<1,140	<930	<350	<1,250
2124	PVC frames	<2,100	<800	<200	<1,500
6017	PVC frames	<1,090	<890	<330	<1,190
7022	PVC frames	<890	<730	<270	<980

Note: Orange shading results above LOQ, red shading above a hazardous threshold

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the 22 door and window frame samples sent for analysis. This category was of particular interest with regards to UV-328 since it is used as a UV light absorber to prevent the degradation of plastics. The loading of UV-328 as an additive during manufacturing is typically 0.1–1% by mass (Hunan

Chemical BV, 2016)[9], however it can also be used as a surface coating. An LOQ of 200 mg/kg is therefore below the concentration that would be expected if UV-328 were used as an additive, but if used as a coating it may be present at lower concentrations in total.

The POPs waste threshold for UV-328 has not yet been determined, and if the limit were to be below this LOQ, then a more sensitive analysis method would be required.

4.5.5. Summary

Chemical screening highlighted phthalates as substances potentially present above HP thresholds for associated hazard statement codes. Since the phthalates were quantified alongside UV-328, a substance classified as a POPs and suspected to be present in this category, all samples of doors and window frame which underwent screening also underwent quantitative analysis for these substances.

UV-328 was not detected above the LOQ of 200 mg/kg, suggesting it is not present in this product as an additive in the polymer. Phthalates were present in some samples, but only two contained phthalates above an associated hazardous property threshold.

One sample of partially flexible plastic door trim was found to contain SCCPs at 5,200 mg/kg, which was below the current POPs threshold of 10,000 mg/kg but significantly greater than a potential future threshold of 1,500 mg/kg. MCCPs were also present in this sample at a concentration above 10,000 mg/kg.

Table 4.62 summarises the results for the quantitative analysis of waste doors and window frame samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Scanning using XRF showed that waste doors and window frames were notably high in lead, with 67% of samples containing lead at concentrations above the H360 and H314 thresholds for HP 10 and HP 14. Additionally, arsenic was present in concentrations above the relevant hazard statement codes for HP 6 and HP 7. This level of potential exceedance is the highest of any category. Table 4.63 provides a rating as to the relative prevalence of the four key elements.

[9] https://hunan-chem.com/wp-content/uploads/2016/06/UV-Absorber-328.pdf

Table 4.62 Summary of the prevalence of classified substances in doors and window frames

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	Two samples contained SCCPs below the current POPs threshold of 10,000 mg/kg but above a potential future threshold of 1,500 mg/kg.
MCCPs	Medium	One sample contained MCCPs at a concentration over 100,000 mg/kg.
Classified BFRs	Low	
Classified phthalates	Medium	Two samples contained phthalates at concentrations exceeding relevant hazardous property thresholds.
Classified OPFRs	Low	

Table 4.63 Summary of key elements in doors and window frames

Element	Relative prevalence	Commentary
Arsenic	Medium	Arsenic, assumed to be present as arsenic trioxide was found at concentrations exceeding HP 6 and HP 7 thresholds for the relevant hazard statement codes in six samples.
Antimony	Low	
Lead	High	Lead, used as a stabiliser in PVC, was present in 67% of samples above both the H360 and H410 thresholds for HP 10 and HP 14 respectively.
Zinc	Low	

Table 4.64 shows the number of samples which exceeded relevant thresholds for the various categories of doors and window frames. The category with the most exceedances is PVC frames, due to lead concentrations.

Table 4.64 Doors and window sample exceeding threshold by category

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)			
		Quantitative	Quantitative		XRF	
		SCCPs	CPs	DEHP/ DIOP	Lead	Zinc
Doors and window frames (all)	78	0 (6)	1 (6)	2 (22)	44	1
PVC frames	51	0* (4)	0 (4)	1 (14)	36	0
PVC fittings/trims	11	-	-	0 (3)	6	0
PVC sills	6	-	-	0 (1)	2	0
Other doors and window frames	10	0* (2)	1 (2)	1 (4)	0	1

*One sample above possible future UK threshold of 1,500 mg/kg.

4.6. Adhesives and Sealants

4.6.1. Sample collection

In total 66 adhesive and sealant samples were collected during this project. The samples collected were divided into three categories outlined in Table 4.65.

Table 4.65 Adhesive and sealant sub-categories

Category	Count	Description
Elastic adhesive and sealant	31	Sealants commonly from a tube based dispensing system which retain their elastic properties after setting. The elastic sealants available on the market consist of various polymers which include: acrylic, bituminous, butyl, hybrid, polyurethane, and silicone polymers, each with its own specific physical-mechanical characteristics and specific areas of use.
Non-elastic adhesive and sealant	32	Hard setting sealant normally used to affix rigid materials such as tile and wood also used for permanently repairing and sealing joints, cracks and fissures in high temperature situations.
Other adhesives and sealants	3	Sealants that did not fit into either category (e.g. tape).

4.6.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded in the adhesive and sealant category are outlined in Figure 4.11.

Bromine was not identified above 1,000 mg/kg in any samples in this category. The highest bromine concentration recorded was 250 mg/kg. A single sample had an antimony concentration above 1,000 mg/kg which did not correspond to an elevated bromine or chlorine concentration.

Chlorine was detected in 11 samples at a concentration above 1,000 mg/kg, five of which had a concentration over 10,000 mg/kg and one with a concentration above 100,000 mg/kg.

Three samples were found to contain lead over 1,000 mg/kg (Table 4.66). Lead (as lead compounds) is classified as H360 and H410 which have the threshold of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. Two samples had concentrations of lead above both these thresholds.

Figure 4.11 Adhesive and sealants XRF results

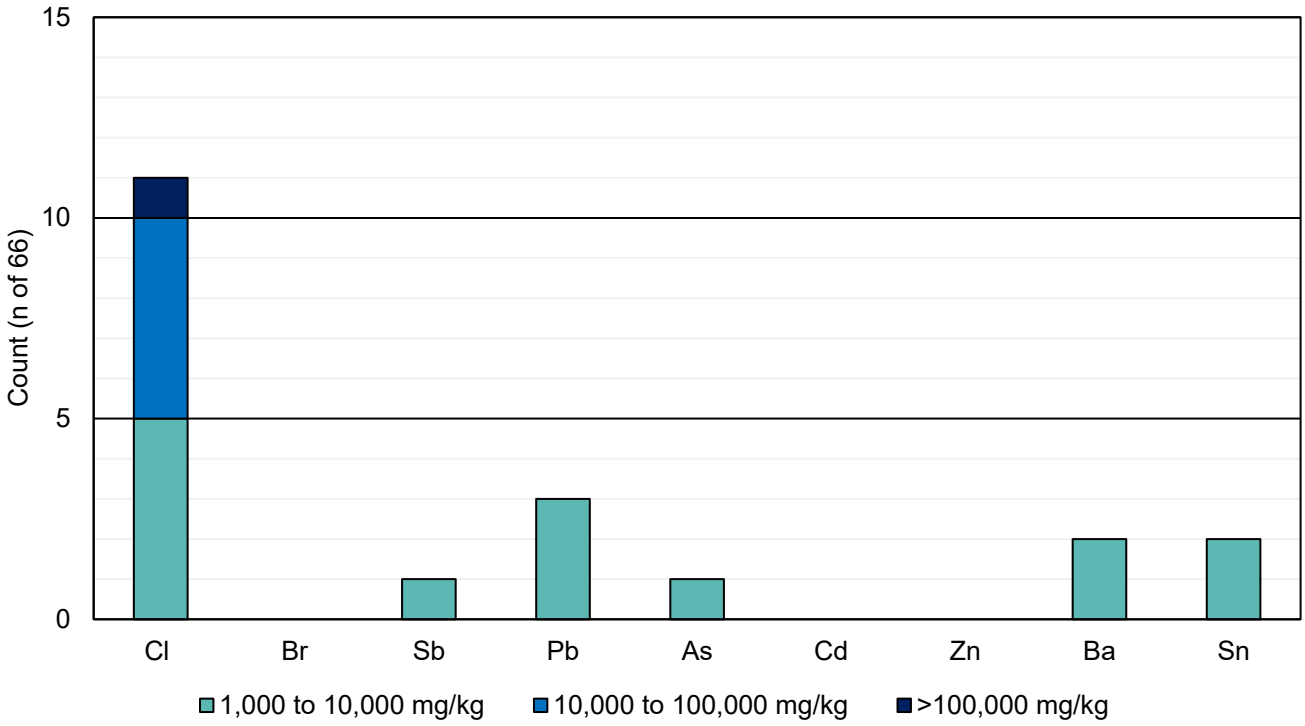


Table 4.66 Adhesive and sealant samples with lead >1,000 mg/kg

Sample	Description	Chlorine(mg/kg)	Lead (mg/kg)
2022	Elastic sealant	76,766	9,041
3069	Non-elastic sealant	1,619	4,881
2092	Elastic sealant	41	1,843

One sample (3071 – elastic sealant) was found to contain arsenic at 1,200 mg/kg, although this sample did not contain any other key element above the threshold of detection. Using the worst-case compound of arsenic trioxide with hazardous statement codes H300, H350 and H360, this sample marginally exceeds the 1,000 mg/kg threshold for H350 and H300 and would therefore be classified as hazardous with HP 6, acute toxicity and HP 7, carcinogenic respectively.

4.6.3. Chemical Screening

Sample selection

The 15 samples selected for chemical screening represents the same proportion of this product in the overall sample population (~7%). Due to the material properties of the elastic sealant, they were more likely to contain compounds of interest and were therefore given slightly higher priority in the screening selection. The breakdown of sample selection by categories is provided in Table 4.67.

Table 4.67 Adhesives and sealants sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Adhesives and sealants (all)	66	15
Elastic sealant	31	10
Non-elastic sealant	32	5
Other adhesives/sealants	3	0

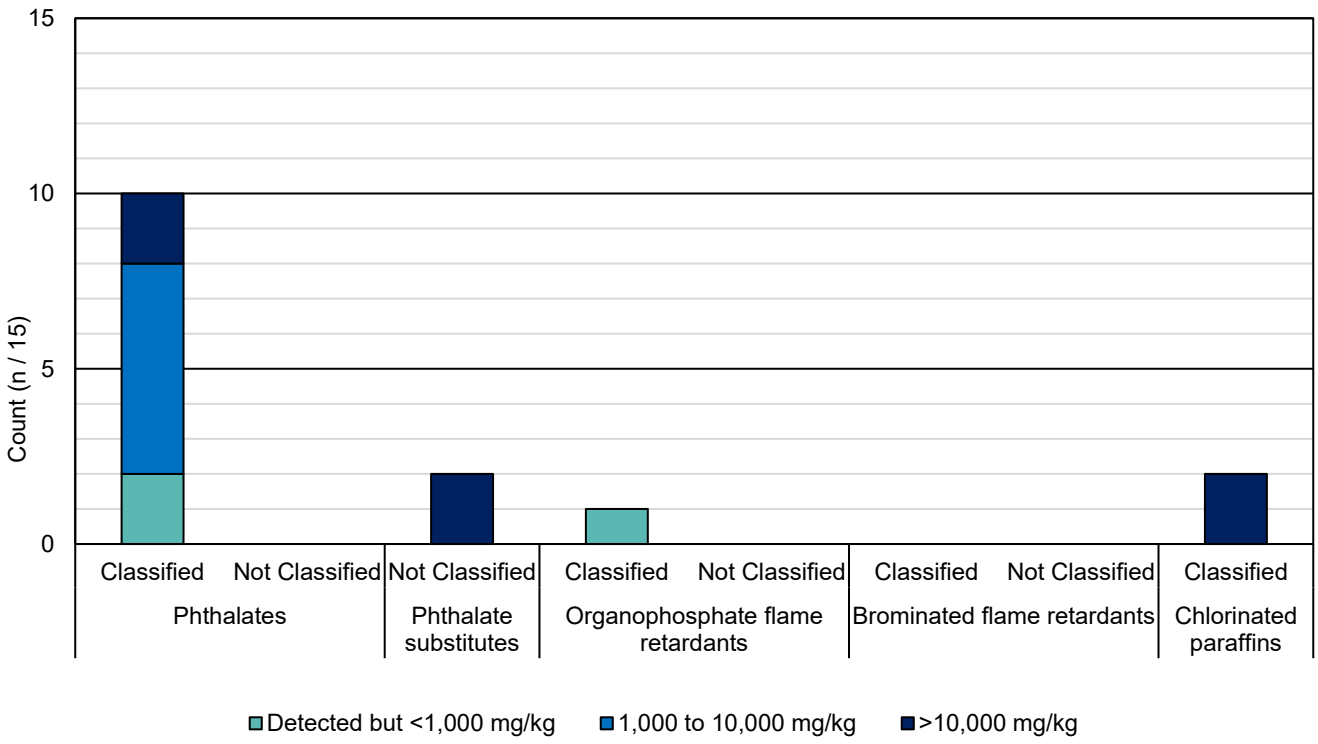
Screening results – POPs

Of the six POPs compounds included in the screening list none were detected. A single sample (2115) was found to contain the phthalate group DBP/DIBP above 10,000 mg/kg. DBP is a compound listed on the ECHA PBT list, as a potential persistent bioaccumulative and toxic (PBT), very persistent and very bioaccumulative (vPvB), however the screening method cannot distinguish between DBP and DIBP.

Screening results – classified substances

Of the 15 samples analysed 11 samples had at least one hazardous substance detected. A breakdown of the compounds detect by analysis category is provided in Figure 4.12.

Figure 4.12 Adhesive and sealant screening results



MCCPs are classified as H410 which has a threshold of 2,500 mg/kg for HP 14. The two samples (3042 and 3071) identified to contain MCCPs above 10,000 mg/kg would

therefore exceed this threshold. As MCCPs are also proposed for listing under the Stockholm convention they could contribute to a CPs POPs exceedance in the future.

Several different classified phthalates were detected during the screening test, with some grouped with unclassified phthalates due to the difficulty in distinguishing the compounds in the screening test. Of the adhesives and sealant samples, nine (60%) contained a classified phthalate, or a group containing a classified phthalate at levels greater than 1,000 mg/kg.

Table 4.68 shows the concentration ranges detected in these nine samples. In one sample BPP was detected at greater than 10,000 mg/kg. This phthalate has H360 and H410 classification, and at this concentration is highly likely to exceed the HP 10, toxic for reproduction, and HP 14, ecotoxic thresholds of 3,000 mg/kg and 2,500 mg/kg respectively. Another sample contained a phthalate group with DBP and DIBP at levels greater than 10,000 mg/kg. Both substances are classified as H360 and therefore it is highly likely the sample exceeds the threshold for HP 10. Only DBP is classified as H410, and so it would only exceed the HP 14 threshold of 2,500 mg/kg if this was the phthalate present.

The remaining sample with greater than 10,000 mg/kg in a group with a classified phthalate contained DINP or DHUNP. DINP is not classified, and so this sample would only exceed the HP 10 threshold if DHUNP were present, which is classified as H360.

Of the remaining samples with between 1,000 and 10,000 mg/kg phthalates detected, one contained the group which includes DIPP which is classified as H360 and H400. Since the H400 threshold is 250,000 mg/kg, it is highly unlikely the sample would exceed this threshold, however it may exceed the H360 threshold of 3,000 mg/kg for HP 10.

The other samples contained either the DINP/DHUNP group or the DEHP/DNOP/DIOP group at between 1,000 and 10,000 mg/kg. Both groups contain phthalates with H360 classifications, however since the exact phthalate cannot be known, and the concentration may be below the 3,000 mg/kg threshold for HP 10 these samples would possibly be classified as hazardous. One of these products (N12) was a newly purchased elastic sealant.

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Table 4.68 Adhesive and sealant phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF scanning (mg/kg)	Screening concentration bands (mg/kg)						HP threshold exceedance	
		Chlorine	DBP/ DIBP	BBP	DIPP/DPP /NPIPP	DINP/ DHUNP	DIHP	DEHP/ DNOP/ DIOP	HP 10	HP 14
2116	Non-elastic sealant	273	>10,000	ND	ND	ND	ND	ND	Highly likely	Likely*
3042	Elastic sealant	547	ND	ND	ND	ND	ND	1,000 – 10,000	Possible	N/A
3069	Non-elastic sealant	1,619	ND	>10,000	ND	1,000 – 10,000	1,000 – 10,000	<1,000	Highly likely	Highly likely
4022	Elastic sealant	1,491	ND	ND	ND	ND	ND	1,000 – 10,000	Possible	N/A
4023	Elastic sealant	151	ND	ND	ND	1,000 – 10,000	ND	1,000 – 10,000	Possible	N/A
4136	Non-elastic sealant	33,938	ND	ND	ND	1,000 – 10,000	ND	<1,000	Possible	N/A
N12	Elastic sealant	15,279	ND	ND	ND	1,000 – 10,000	<1,000	<1,000	Possible	N/A
R064	Elastic sealant	496	ND	ND	ND	<1,000	ND	1,000 – 10,000	Possible	N/A
7026	Non-elastic sealant	41	ND	ND	1,000 – 10,000	>10,000	ND	<1,000	Likely*	Highly unlikely

*Highly likely cannot be concluded since the phthalate present may be the un-classified substance in the group for the hazardous property

4.6.4. Quantitative analysis

Sample Selection

A total of 13 samples were selected for quantitative testing. Justification for selection is provided in Table 4.69.

Table 4.69 Adhesives and sealants sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	0/51	No BFRs detected and not identified as a likely source.
SCCPs and MCCPs	9/62	The samples where CPs were detected were selected along with samples with a range of chlorine concentrations in both the elastic and non-elastic sealant sub-categories.
Phthalate and UV-328	9/67	Selection of both samples with very high phthalates, a variety of samples with elevated phthalates in addition to a sample where no phthalates were detected. UV-328 was not a selection factor as it was considered unlikely it would be present in the stream.
PFAS	13/20	High priority category for analysis due to the documented addition to improve desired material properties.
OPFRs	0/20	Screening did not identify any samples with >1,000 mg/kg OPFRs, and so unlikely to be present above relevant hazardous thresholds.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.70.

Table 4.70 Adhesives and Sealants chlorinated paraffins quantitative results

Sample	Category	SCCPs(mg/kg)	MCCPs (mg/kg)
2022	Elastic sealant	<800	<800
2100	Elastic sealant	<500	<500
3042	Elastic sealant	<600	17,400
3069	Non-elastic sealant	<500	<500
3071	Elastic sealant	<500	210,380
4022	Elastic sealant	<600	5,500
4058	Non-elastic sealant	<600	<600
4136	Non-elastic sealant	<600	<600
N12	Elastic sealant	1,600	18,300

Of the nine adhesive and sealant samples sent for quantitative CPs analysis a single newly purchased elastic sealant sample had an SCCPs concentration (above the LOD) of 1,600 mg/kg.

This concentration was below the current UK threshold (10,000 mg/kg) but could be above potential future thresholds (e.g. 1,500 mg/kg). SCCPs were not detected in this sample during screening. MCCPs were detected in four of the elastic sealant samples sent for quantification, one with concentrations above 100,000 mg/kg and two above 10,000 mg/kg.

As MCCPs are a substance proposed for listing under the Stockholm Convention, if they were to be included in future POPs assessments this would have a major impact on the POPs exceedance rate for this category. All four of the samples with MCCPs quantified had a concentration above the H410 threshold (2,500 mg/kg) for HP 14 - ecotoxic.

Phthalates

The results of the phthalate analysis are provided in Table 4.71. Samples 2116 and 3069 were both found to contain DIBP and BBP, these phthalates are classified as H360. As the HP 10 hazardous threshold for H360 is 3,000 mg/kg both samples exceed this threshold with different phthalate compounds. BBP is also classified as H410, with a threshold of 2,500 mg/kg for HP 14, meaning this is also exceeded in this sample.

Table 4.71 Adhesives and sealants phthalate quantitative results

Sample	Category	Classified (hazard statement codes) (mg/kg)			Not classified (mg/kg)				
		DIBP	BBP	DEHP/ DIOP	DINP	DNOP	DIDP	DINCH	ATBC
2116	Non-elastic	25,080	<40	<1,900	<600	<40	<1,200	<200	<2,100
3069	Non-elastic	<1,600	16,280	<1,600	<500	1,170	25,900	<100	<1,800
4022	Elastic	<2,200	<50	<2,300	<700	<50	<840	<200	<2,500
4058	Non-elastic	<2,000	<40	<2,100	<600	<40	1,120	<200	<2,200
4136	Non-elastic	<2,200	<50	<2,300	13,060	<50	24,820	<200	11,510
N12	Elastic	<2,300	<50	<2,400	<700	<50	102,030	<200	<2,600
R032	Elastic	<2,100	<40	<2,200	<700	<40	<800	<200	<2,300
R064	Elastic	<2,000	<40	8,120	<600	<40	19,080	31,130	<2,200
7026	Non-elastic	<2,000	<40	<2,100	142,540	<40	7,410	<200	<2,300

Note: Orange shading results above LOQ, red shading above a hazardous threshold

Sample R064 has a DEHP/DIOP concentration of 8,120 mg/kg. Both compounds in this group have the hazardous classification H360, and since the concentration of each cannot

be determined it must be assumed one is present at this level. This sample exceeds the H360 threshold for HP 10 of 3,000 mg/kg.

Alongside these classified phthalates, phthalates and plasticisers which are not classified with hazard statement codes are also present. Classification of substances is subject to change, and in the future some of these may be assigned hazard statement codes.

UV-328

UV-328 was not detected above the LOQ of between 100 and 200 mg/kg in the nine adhesive and sealant samples sent for quantitative analysis.

PFAS

Of the 13 samples sent for quantitative PFAS analysis none of the listed PFAS compounds were identified above the LOQ of 5 µg/kg.

Polychlorinated Biphenyls (PCBs)

Of the 25 samples selected for PCB analysis, the main focus was on the adhesive and sealant category with 21 samples selected. This is because PCBs were commonly added to these products to provide flexibility and adhesive properties. The results of the analysis are provided below in Table 4.72.

All samples were shown to be well below the POPs threshold of 50 mg/kg for total PCB content. One sample had a total PCB concentration of 9 mg/kg, which was a window sealant. All other samples contained 1 mg/kg or less.

The ratio of ICES6 to total PCB content was on average 0.33. This ratio was mostly consistent amongst the samples, with 68% of samples having a ratio of between 0.32 and 0.4. This data is based on a limited number of samples, but if more data is collected it may provide evidence on how ICES6 analysis could be scaled to estimate total PCB concentration.

The dioxin like PCB (dl-PCB) concentration was also very low in all samples. The highest concentration measured was 0.08 mg/kg, which was in the same sample that had the greatest total PCB concentration. When scaled using the WHO 2005 TEFs, the TEQ value for all samples was well below the EU POPs threshold of 5 µg/kg (5,000 ng/kg) with the highest upper bound value measured being 0.024 µg/kg (23.6 ng/kg). When using the WHO 2022 TEFs, most samples show a reduction in TEQ, which is most prominent in sample 4136 due to the reduction of the TEF for PCB 126 from 0.1 to 0.05.

The analysis by MSS demonstrated high recovery rates for the spiked samples. The average recovery observed for the dl-PCBs was 89% (+/-2%), and for the ICES6 was 80% (+/-3%).

Table 4.72 Adhesive and sealants PCBs quantitative analysis results

Category	Sample	Sum of total PCB (mg/kg)	Sum of ICES6 (mg/kg)	Sum of dl-PCB (mg/kg)	dl-PCB WHO 2005 TEQ (ng/kg)	dl-PCB WHO 2022 TEQ (ng/kg)
Elastic sealant	2090	0.041	0.016	0.005	0.34	0.30
	2092	9.097	1.010	0.081	11.60	13.96
	3046	0.101	0.037	0.001	1.52	0.86
	3066	0.068	0.026	0.003	0.78	0.54
	4022	0.042	0.014	0.002	0.74	0.49
	4023	0.045	0.016	0.003	0.82	0.52
	4055	0.071	0.009	0.018	6.79	4.35
	5031	0.009	0.004	0.000	0.29	0.17
	5053	0.101	0.024	0.004	0.73	0.49
	5055	0.046	0.018	0.001	0.44	0.29
	R032	0.025	0.011	0.002	0.79	0.46
	R034	0.045	0.014	0.001	0.62	0.39
Non-elastic sealant	4046	0.057	0.019	0.001	0.56	0.35
	4058	0.018	0.006	0.001	0.55	0.33
	4130	0.022	0.006	0.001	0.41	0.26
	4136	0.064	0.022	0.007	23.60	12.32
	5001	0.035	0.012	0.003	0.63	0.57
	5046	0.041	0.016	0.003	1.34	0.77
	5047	0.022	0.007	0.000	0.28	0.17
	R003	0.021	0.007	0.001	0.53	0.31
Other	5059	0.081	0.018	0.002	0.55	0.37

Note: orange shading >1 mg/kg.

4.6.5. Summary

Chemical screening highlighted phthalates as substances with hazard statement codes potentially present above HP thresholds. On this basis, nine samples were chosen for quantitative analysis of phthalates. A further nine samples were selected for chlorinated paraffin quantification.

Through quantitative analysis, three samples were found to contain classified phthalates in concentrations above relevant thresholds. Due to a relatively high LOQ for phthalates in this study, it is possible more samples contained classified phthalates below relevant thresholds.

MCCPs were quantified at concentrations exceeding the H410 threshold for HP 14 in four samples, with one sample found to contain over 200,000 mg/kg MCCPs. Another sample, a newly purchased elastic sealant, contained 1,600 mg/kg SCCPs and 18,300 mg/kg MCCPs. Although this SCCPs concentration is below the current POPs threshold, it is above a potential future threshold of 1,500 mg/kg. Since this was a newly manufactured product, it highlights the risk of restricted substances continuing to enter the construction sector, which will have an impact on waste classification in the future.

Table 4.73 summarises the results for the quantitative analysis of adhesive and sealant samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Aside from lead present in two samples above 3,000 mg/kg, XRF scanning did not highlight any other potential classified substances present above threshold levels. Table 4.74 summarises the relative prevalence of the key elements.

Table 4.73 Summary of the prevalence of classified substances in adhesives and sealants

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
PCBs	Low	
UV-328	Low	
SCCPs	Medium	SCCPs were quantified in one sample at 1,600 mg/kg in a newly manufactured product.
MCCPs	High	Four samples were found to contain MCCPs at concentrations over the H410 threshold for HP 14.
Classified BFRs	Low	
Classified phthalates	Medium	Quantitative analysis identified three samples that contained classified phthalates above HP thresholds. Phthalates and plasticisers without hazard statement codes were more prevalent than classified substances.
Classified OPFRs	Low	

Table 4.74 Summary of key elements in adhesives and sealants

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	Medium	Two samples contained lead above 3,000 mg/kg which exceeds both the H360 and H410 thresholds for HP 10 and HP 14 respectively.
Zinc	Low	

Table 4.75 shows the number of samples which exceeded relevant thresholds for the three types of adhesives and sealant. Elastic sealant is the category where MCCPs concentrations were above the H410 threshold.

Table 4.75 Adhesive and sealant samples exceeding threshold

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)				
		Quantitative	Quantitative				XRF
		SCCPs	CPs	DIBP	BBP	DEHP / DIOP	Lead
Adhesives and sealants (all)	66	0 (9)	4 (9)	1 (9)	1 (9)	1 (9)	2
Elastic sealant	31	0* (6)	4 (6)	0 (4)	0 (4)	1 (4)	1
Non-elastic sealant	32	0 (3)	0 (3)	1 (5)	1 (5)	0 (5)	1
Other adhesives/ sealants	3	-	-	-	-	-	0

*One sample above possible future UK threshold of 1,500 mg/kg.

4.7. Cladding and Wall Panels

4.7.1. Sample collection

A total of 66 cladding and wall panel samples were collected for analysis. The samples were divided into six categories for assessment as outlined in Table 4.76.

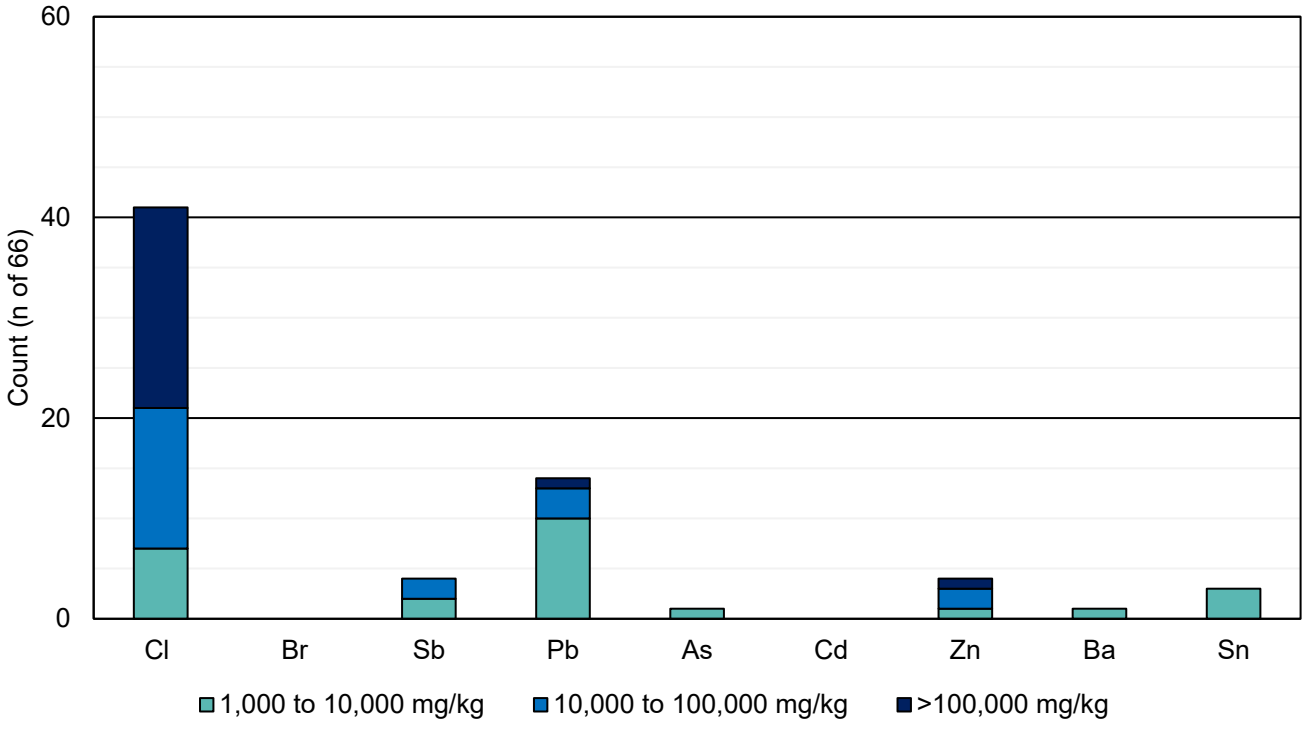
Table 4.76 Cladding and wall panel categories

Category	Count	Description
External plastic cladding	18	Plastic used in facing of external walls (predominantly PVC).
Plaster / mineral board	14	Internal brittle mineral board with paper facing.
Inner plastic wall	4	Plastic items used in the structure of inner walls.
Plastic wall coverings	21	Plastic items used in the facing of internal walls.
Tiles	3	Ceramic modular wall covers.
Other wall coverings	6	Other wall components which did not fit the outlined categories (e.g. barrier membranes).

4.7.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded for the cladding and wall panel category are outlined in Figure 4.13.

Figure 4.13 Cladding and wall panels XRF results



No samples contained bromine above 1,000 mg/kg, with the highest level detected at 350 mg/kg.

Four samples had an antimony concentration above 1,000 mg/kg, two of which had a concentration above 10,000 mg/kg. All of these samples also had a chlorine concentration above or close to 100,000 mg/kg. These samples are shown in Table 4.77.

Table 4.77 Cladding and wall panels with antimony >1,000 mg/kg

Sample	Description	Antimony (mg/kg)	Chlorine (mg/kg)
1027	External plastic cladding	43,056	194,443
4035	Plastic wall cover	40,188	146,232
5076	External plastic cladding	4,490	164,977
5021	Plastic wall cover	1,163	86,549

Antimony is likely to be present as antimony trioxide to provide flame retardancy in products made from chlorinated polymers, or with chlorinated flame retardant additives. Antimony trioxide is classified as H351, and therefore two samples may be above the 10,000 mg/kg threshold for HP 7, carcinogenic.

Of the cladding samples analysed 41 (62%) contained a chlorine above 1,000 mg/kg of which 20 (30%) had a concentration above 100,000 mg/kg, indicating they are made from PVC.

Lead was present in 14 samples above 1,000 mg/kg, with one sample containing over 100,000 mg/kg. This sample with high lead content is likely to be a coating, such as paint, containing lead. Although most samples with lead above 1,000 mg/kg also contained chlorine above 10,000 mg/kg, the level of chlorine was lower than would be expected for PVC, indicating that the chlorine may be present as a different polymer or the product has a coating which is preventing accurate quantification. Table 4.78 shows the samples with lead detected at levels over 1,000 mg/kg.

Lead (as lead compounds) is classified as H360 and H410 and has thresholds of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. Although lead may be present only on the surface, and representative quantitative analysis is required on the whole sample, it is possible that 13 samples (20%) would be classified as hazardous with both HP 10, carcinogenic, and HP 14, ecotoxic.

Table 4.78 Cladding and wall panels with lead >1,000 mg/kg

Sample	Description	Lead (mg/kg)	Chlorine (mg/kg)
1172	Tile	125,349	2,895
6008	External plastic cladding	19,273	47,728
7009	External plastic cladding	13,133	7,7146
3128	External plastic cladding	12,900	223,696
R010	External plastic cladding	8,372	283,868
3019	Tile	7,633	368
7013	Plastic wall cover	7,593	23,593
7059	Plastic wall cover	6,894	67,598
2074	External plastic cladding	6,276	218,633
7052	Plastic wall cover	6,084	66,935
7017	Plastic wall cover	5,499	9,306
7057	Plastic wall cover	4,935	89,386
7010	Plastic wall cover	4,482	35,704
3015	Tile	1,340	333

Zinc was present in four samples at levels greater than 1,000 mg/kg, with over 100,000 mg/kg detected in one sample. These samples were primarily tiles and it is therefore likely the zinc is present as zinc oxide which is often used in ceramics. The remaining sample was a woven plastic sheet, where zinc oxide may also be present as an additive. Table 4.79 provides the details of the four samples discussed.

Table 4.79 Cladding and wall panels with zinc >1,000 mg/kg

Sample	Description	Zinc (mg/kg)
3015	Tile	256,348
3019	Tile	96,243
1172	Ceramic wall/floor tile	28,126
4035	Woven plastic sheet	8,763

Zinc oxide is classified as H410, and it is likely therefore that all four samples would exceed the 2,500 mg/kg threshold for HP 14 and may be classified as hazardous.

4.7.3. Chemical screening

From the classing and wall panel category, 18 samples were selected for chemical screening, resulting in slight over representation of this product (cladding and wall panels represented 6% of all samples taken but 9% of all samples sent for chemical screening).

This is because cladding material was not readily available at the majority of sites however the category is of particular interest due to their strict flame retardancy requirements. Samples selected include the tile sample along with several other plastic sample with elevated lead. Four samples with elevated antimony were selected as well as samples with a range of chlorine concentrations. The breakdown of sample selection by categories is provided in Table 4.80.

Table 4.80 Cladding and wall panel sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Cladding and wall panels (all)	66	18
External plastic cladding	18	9
Plaster/mineral board	14	0
Inner plastic wall	4	0
Plastic wall cover	21	8
Tile	3	1
Other wall cover	6	0

Screening results – POPs

Of the six POPs compounds included in the screening list, SCCPs were detected in one sample. Table 4.81 outlines the details of the sample.

Table 4.81 Cladding and wall panel POPs screening results

Sample	Description	XRF analysis (mg/kg)			Screening analysis (mg/kg)
		Br	Sb	Cl	SCCPs
4002	Wallpaper with plastic mesh	109	<18	98,457	1,000 – 10,000

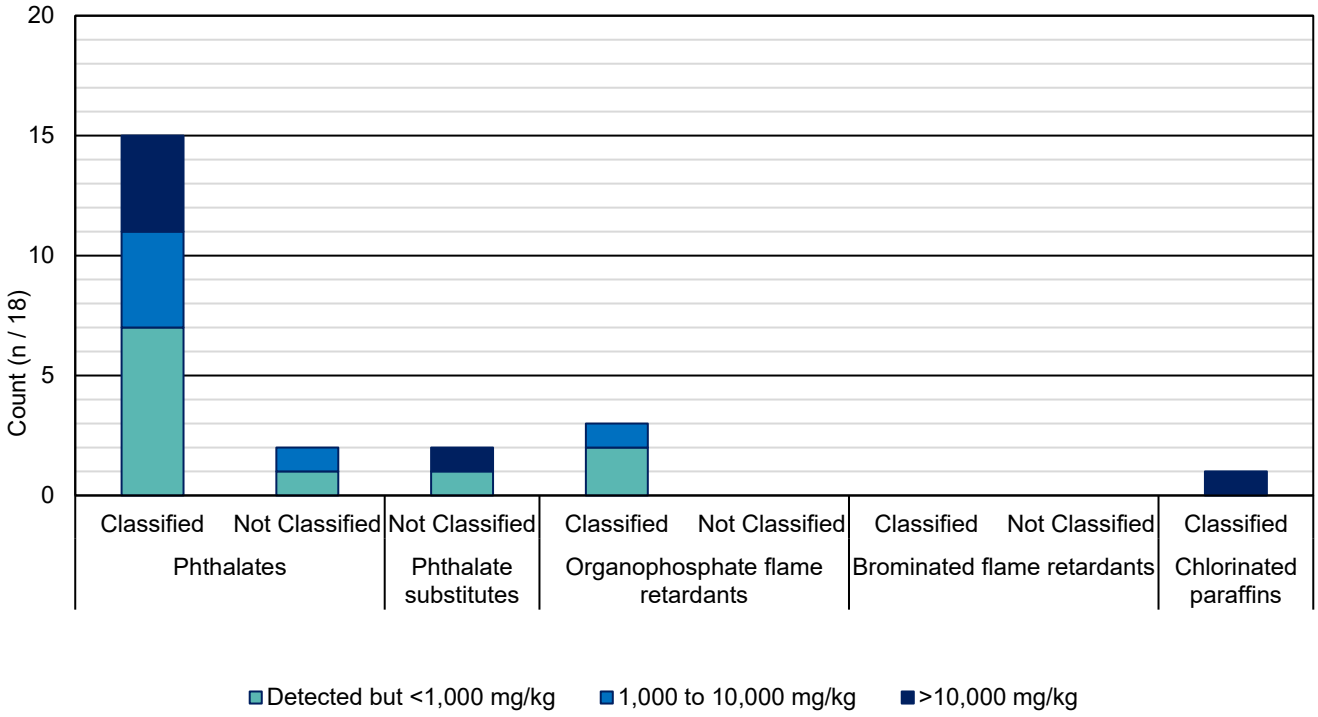
As the concentration of SCCPs were found to be between 1,000 and 10,000 mg/kg this sample would likely not exceed the POPs threshold of 10,000 mg/kg but may be above a future POPs threshold (1,500 mg/kg). MCCPs were also found in this sample above 10,000 mg/kg. As MCCPs are proposed for listing under the Stockholm Convention they could contribute to a CPs POPs exceedance of this sample in the future.

No other sample was found to contain POPs or chemicals proposed for listing under the Stockholm Convention.

Screening results – classified substances

Of the 18 samples sent for screening, eight were identified to contain substances with a hazardous classification. A summary of the substances detected by substance type is provided in Figure 4.14.

Figure 4.14 Cladding and wall panel screening results



MCCPs are classified as H410 with a threshold of 2,500 mg/kg for HP 14. The sample identified to contain MCCPs above 10,000 mg/kg would therefore likely exceed this threshold.

Classified phthalates, or groups of phthalates which include a classified substance, were detected in eight samples at levels over 1,000 mg/kg. These samples are shown in Table 4.82. Four samples contained phthalates with a concentration over 10,000 mg/kg, with the group containing DINP/DHUNP and DEHP/DNOP/DIOP being the most prevalent.

All samples potentially contain a phthalate classified as H360, which has a corresponding hazardous threshold of 3,000 mg/kg for HP 10, toxic for reproduction. Four samples are likely to be above this threshold, with three samples possibly above the threshold. However, since the exact phthalate cannot be distinguished, it is possible the un-classified phthalate in the group is present and therefore the sample would not be classified as hazardous.

Table 4.82 Cladding and wall panel phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening (mg/kg)			HP threshold exceedance
		Chlorine	DINP/ DHUNP	DIHP	DEHP/ DNOP/ DIOP	HP 10
3086	Plastic wall cover	297,480	ND	ND	>10,000	Likely*
4002	Plastic wall cover	98,457	ND	1,000 – 10,000	>10,000	Likely*
4035	Plastic wall cover	146,232	>10,000	ND	ND	Likely*
4103	Plastic wall cover	200,592	1,000 – 10,000	ND	ND	Possible
5021	Plastic wall cover	86,549	>10,000	<1,000	>10,000	Likely*
5076	External plastic cladding	164,977	1,000 – 10,000	ND	1,000 – 10,000	Possible
7009	External plastic cladding	77,146	ND	ND	1,000 – 10,000	Possible
7052	Plastic wall cover	66,935	ND	ND	1,000 – 10,000	Possible

*Highly likely cannot be concluded as the phthalate present may not be classified.

All samples potentially contain a phthalate classified as H360, which has a corresponding hazardous threshold of 3,000 mg/kg for HP 10, toxic for reproduction. Four samples are likely to be above this threshold, with three samples possibly above the threshold. However, since the exact phthalate cannot be distinguished, it is possible the un-classified phthalate in the group is present and therefore the sample would not be classified as hazardous.

Sample 4002 which was identified to contain CPs also contained two hazardous OPFRs, triphenyl phosphate (TPP) and tricresyl phosphate (TCP)[10], both at a concentration between 1,000 and 10,000 mg/kg. Both compounds have a classification of H410 which has a hazardous threshold for HP 14 of 2,500 mg/kg. As the bottom of the screening band is above the HP 14 contribution threshold (1,000 mg/kg) then this sample has a high likelihood of being close to or exceeding this threshold.

4.7.4. Quantitative analysis

Sample Selection

[10] Also known as Tris(methylphenyl) phosphate, CAS number 1330-78-5

A total of eight samples were selected for quantitative testing. Justification for selection is provided in Table 4.83.

Table 4.83 Cladding and wall panel sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	0/51	No BFRs detected during screening and not identified as likely source.
SCCPs and MCCPs	4/62	The samples where CPs were detected were selected along with samples with elevated chlorine and elevated antimony or lead.
Phthalates and UV-328	5/67	Samples found to contain hazardous phthalates as well as some external cladding samples which may contain UV-328.
PFAS	1/20	PFAS can be used as waterproofing and so one sample was selected for testing.
OPFRs	1/20	Sample with hazardous OPFRs between 1,000 and 10,000 mg/kg.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.84.

Table 4.84 Cladding and wall panel chlorinated paraffin quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
1027	External plastic cladding	<500	10,500
4002	Plastic wall cover	2,600	56,000
5076	External plastic cladding	<600	<600
7057	Plastic wall cover	<500	<500

Note: Orange shading above LOQ, red shading hazardous property threshold exceeded

One sample (4002) was found to contain SCCPs above the LOQ with a concentration of 2,600 mg/kg. This concentration is below the current UK threshold (10,000 mg/kg) but above a potential future threshold (1,500 mg/kg). MCCPs were also detected in this sample at a concentration of 56,000 mg/kg. As MCCPs are proposed for listing under the Stockholm Convention, if it were to be included in future CPs POPs assessments this could alter the POPs classification of this sample.

A second sample was also found to contain MCCPs at 10,500 mg/kg, which could also result in a POPs classification if MCCPs were to be listed under the Stockholm Convention.

As both MCCPs and SCCPs have a classification of H410 which has a HP 14, ecotoxic, threshold of 2,500 mg/kg both samples would exceed this hazardous threshold.

The screening analysis only identified MCCPs to be present in sample 4002 although, SCCPs were not detected. MCCPs were not detected in sample 1027 despite being identified at over 10,000 mg/kg.

Phthalates

The results of the phthalate analysis are provided in Table 4.85. A single sample was found to contain the DEHP/DIOP phthalate group above a concentration of 14,000 mg/kg. As both substances in this group are classified as H360, with a HP 10 hazardous threshold of 3,000 mg/kg, the concentration in this sample would exceed the threshold regardless of which substance is present. Phthalates and phthalate substitutes without classification were present in three other samples above the LOQ.

Table 4.85 Cladding and wall panels phthalate quantitative results

Sample	Category	Classified (hazard statement codes) (mg/kg)	Not classified (mg/kg)			
		DEHP/DIOP	DINP	DIDP	DINCH	ATBC
1027	External plastic cladding	<2,100	<600	1,940	<200	<2,200
1172	Tile	<2,400	<700	1,670	<200	8,570
2066	External plastic cladding	14,450	<600	<800	<200	<2,300
4103	Plastic wall cover	<2,000	7,770	51,820	72,620	<2,200
7009	External plastic cladding	<980	<800	<800	<900	<820

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the five samples sent for analysis. As with UPVC windows and doors, cladding was a product where UV protection, such as that provided by UV-328, may be required. The analysis does not show concentrations of UV-328 that would be expected if present as an additive in the polymer (0.1 – 1% by weight).

PFAS

Sample 4002 was sent for quantitative analysis of PFAS. No compounds were detected above the LOQ of 5 µg/kg.

Organophosphate flame retardants

The results of the quantitative OPFRs analysis are provided in Table 4.86.

Table 4.86 Cladding and wall panels organophosphate quantitative results

Sample	Description	TPP (mg/kg)	TCP (mg/kg)
4002	Plastic wall cover	7,840	4,830

Note: Orange shading above LOQ, red shading hazardous property threshold exceeded

As TPP and TCP have a classification of H410 they have a combined threshold for HP 14 of 2,500 mg/kg. This sample therefore exceeds this threshold by each compound separately. The quantitative results for this sample match up well with the results of the screening analysis.

4.7.5. Summary

Relatively few cladding and wall panel samples were submitted for quantitative analysis as samples of potential interest were not highlighted by the chemical screening. Concentrations greater than 10,000 mg/kg were quantified in two samples, with one of these also containing 2,600 mg/kg SCCPs. Another sample was found to contain two classified OPFRs above their hazard thresholds of 2,500 mg/kg for HP 14.

Table 4.87 summarises the results for the quantitative analysis of cladding and wall panel samples. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the waste stream as a whole. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

As with doors and window frames, lead was prevalent in cladding and wall panels and was detected at concentrations over 3,000 mg/kg in 20% of samples, which exceeds the H360 and H410 thresholds for lead compounds. Unlike the doors and windows, zinc was also detected in four samples above 2,500 mg/kg. If present as zinc oxide this would exceed the 2,500 mg/kg H410 threshold for HP 14.

Antimony was present in two samples at concentrations over 40,000 mg/kg. If present as antimony trioxide, this would far exceed the H351 threshold of 10,000 mg/kg for HP 7. Table 4.88 shows the relative prevalence of key elements indicating potential classified substances.

Table 4.87 Summary of the prevalence of classified substances in cladding and wall panels

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	SCCPs were quantified in one sample at 2,600 mg/kg, which is below the current POPs threshold of 10,000 mg/kg but above a potential future threshold of 1,500 mg/kg.
MCCPs	Medium	Two samples were found to contain MCCPs at concentrations over 10,000 mg/kg, which is above the H410 threshold for HP 14.
Classified BFRs	Low	
Classified phthalates	Medium	DEHP/DIOP was measured in one sample at a concentration over 10,000 mg/kg, exceeding the H360 threshold for HP 10.
Classified OPFRs	Low	

Table 4.88 Summary of key elements in cladding and wall panels

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Medium	XRF scanning detected antimony at concentrations over the H351 threshold for HP 7 in four samples.
Lead	High	20% of all samples collected showed a concentration of over 3,000 mg/kg lead through XRF scanning.
Zinc	Medium	XRF scanning detected zinc in exceedance of the H410 threshold of zinc oxide for HP 14 (2,500 mg/kg) in two samples.

Table 4.89 identifies the number of samples within each category where exceedances in threshold limits were observed.

Table 4.89 Cladding and wall samples above threshold

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)					
		Quantitative	Quantitative			XRF		
		SCCPs	CPs	DEHP/ DIOP	TCP	Lead	Zinc	Antimony
Cladding and wall panels (all)	66	0 (4)	2 (4)	1 (5)	1 (1)	13	4	2
External plastic cladding	18	0 (2)	1 (2)	1 (3)	-	5	-	1
Plaster/mineral board	14	-	-	-	-	-	-	-
Inner plastic wall	4	-	-	-	-	-	-	-
Plastic wall cover	21	0* (2)	1 (2)	0 (1)	1 (1)	6	1	1
Tile	3	-	-	0 (1)	-	2	3	-
Other wall cover	6	-	-	-	-	-	-	-

*One sample above possible future UK threshold of 1,500 mg/kg.

4.8. Rubber Products

4.8.1. Sample collection

A total of 62 rubber products were collected during sampling. Over half (32) of the samples collected consisted of the rubber seal from doors and window frames, but additional samples were collected from a range of sources such as matting and membranes. Table 4.90shows the number of items collected per category.

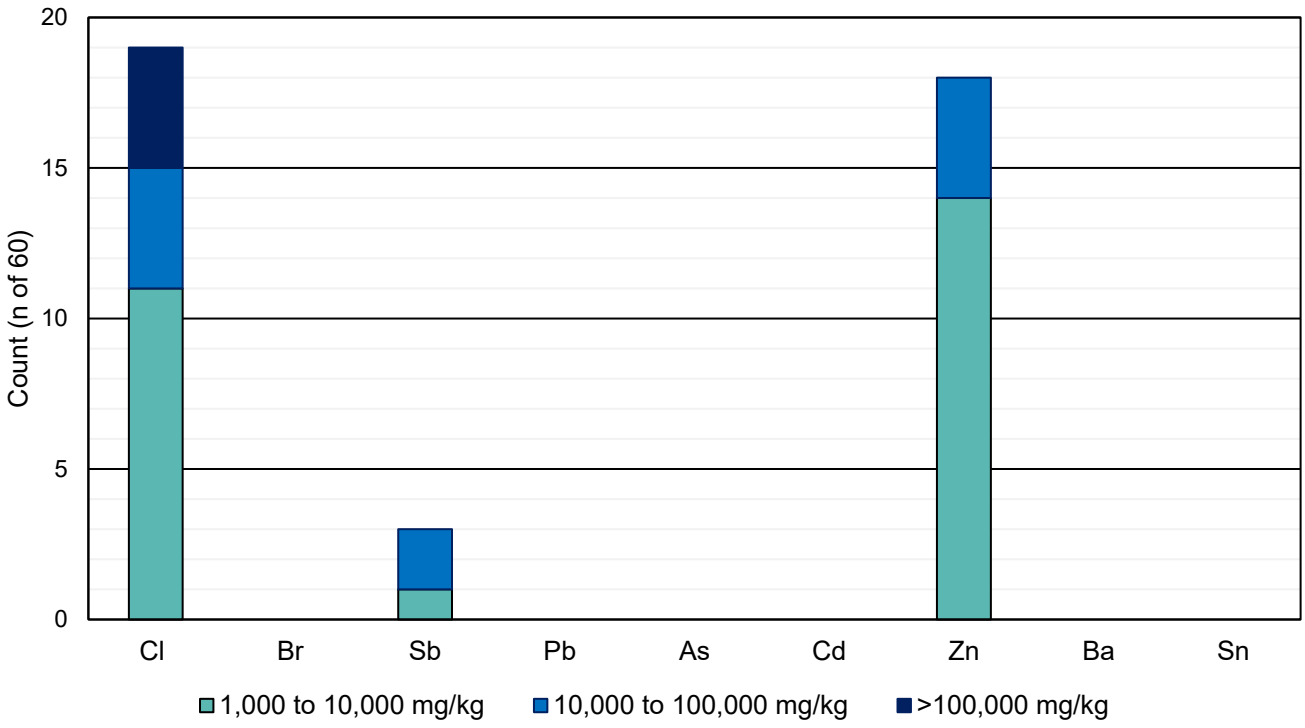
Table 4.90 Rubber products categories

Category	Count	Description
Window/door seals	39	Seals taken from UPVC windows and doors.
Other seals/gaskets	7	Seals and gaskets from products other than UPVC windows and doors, or that could not be conclusively attributed to windows or doors.
Other rubber products	16	Products including rubber matting, membranes and pipes as well as rubber items of unknown origin.

4.8.2. XRF scanning

All samples collected underwent XRF analysis scanning in triplicate. The range of target element concentrations recorded in the adhesive and sealant category are outlined in Figure 4.15.

Figure 4.15 Rubber products XRF results



Bromine was not detected in any rubber samples analysed above 1,000 mg/kg.

Antimony was found to be present above 1,000 mg/kg in three samples, two of which had a concentration above 10,000 mg/kg. All three samples also had chlorine concentrations above 100,000 mg/kg, indicating they may be a halogenated polymer, possibly PVC or neoprene. These samples are shown in Table 4.91.

Table 4.91 Rubber samples with >1,000 mg/kg antimony

Sample	Category	Antimony (mg/kg)	Chlorine (mg/kg)
5038	Window/door seals	68,905	110,810
1043	Other rubber product	13,488	198,664
1174	Other rubber product	4,523	118,680

Antimony is likely to be present as antimony trioxide, a synergist to improve flame retardancy in halogenated compounds, including PVC. Antimony trioxide is classified as H351 with a HP 7, carcinogenic, threshold of 10,000 mg/kg. It is therefore likely that two samples of rubber products exceed this threshold and could be classified as hazardous with HP 7.

Of the rubber samples collected, 19 (31%) had a chlorine concentration above 1,000 mg/kg of which four had a concentration above 100,000 mg/kg. Of these samples, 11 had a chlorine concentration between 1,000 and 10,000 mg/kg, suggesting they were not PVC, rather that the chlorine was present as a chlorinated additive, potentially chlorinated paraffins.

One sample (2231 which was a window seal) was identified to contain lead above 10,000 mg/kg, however the chlorine concentration was below 10,000 suggesting this was not a PVC product and the lead was present in a form other than a lead stabiliser. Lead (as lead compounds) is classified as H360 and H410 which have a threshold of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. With 11,360 mg/kg of lead detected in this sample, it is likely it would be above both thresholds and therefore classified as hazardous with HP 10 and HP 14.

Zinc was found to be above 1,000 mg/kg in 17 (27%) samples. This is to be expected as zinc oxide is a common additive in rubber products. Of these 17 samples, 15 were found to contain zinc at concentrations over 2,500 mg/kg. If present as zinc oxide, which is classified as H410, this may exceed the hazardous threshold for HP 14.

4.8.3. Chemical Screening

Sample selection

A total of eight rubber products were selected for chemical screening, resulting in slight under representation of this product (rubber products represented 6% of all samples taken but 4% of all samples sent for chemical screening). The main justification for this was that the low bromine, antimony and lead content indicated the stream did not contain a high range of problematic materials. Samples selected included the two samples with antimony

above 10,000 mg/kg and samples with a range of chlorine concentrations and from a range of sources. The breakdown of sample selection by categories is provided in Table 4.92.

Table 4.92 Rubber products sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Rubber products (all)	62	8
Window/door seals	39	5
Other seals/gaskets	7	1
Other rubber products	16	2

Screening results – POPs

Of the six POPs compounds included in the screening list, none were detected.

No substances proposed for listing under the Stockholm Convention (i.e. MCCPs) were detected in this category either, however two samples were found to contain TOTM (Tris(2-ethylhexyl) benzene-1,2,4-tricarboxylate). TOTM is a phthalate substitute and is under assessment by ECHA as persistent, bioaccumulative and toxic (PBT) and endocrine disrupting (ED). TOTM has no hazardous classification. This data is provided in Table 4.93.

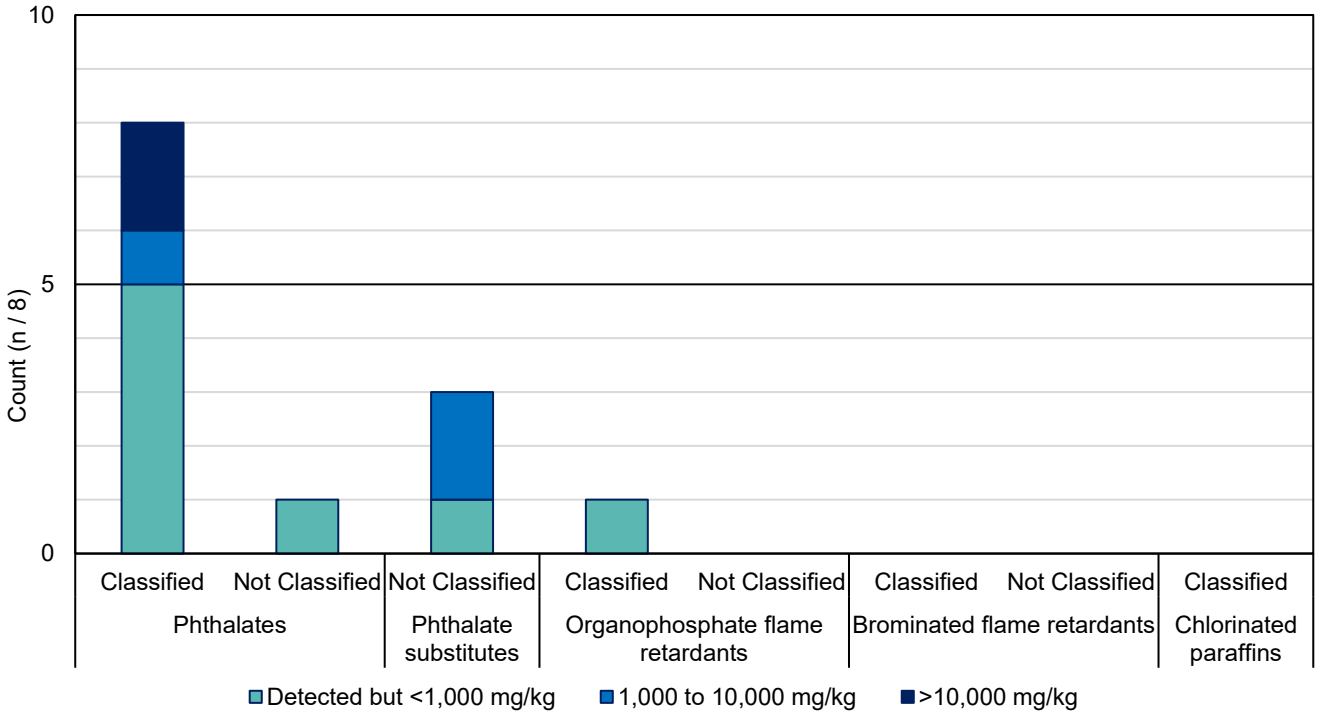
Table 4.93 Rubber products POPs screening results

Sample	Category	TOTM (mg/kg)
1043	Other rubber products	0 – 1,000
4104	Other rubber products	1,000 – 10,000

Screening results – classified substances

Of the eight samples sent for screening analysis, seven were found to contain substances with hazard statement codes. A breakdown of the compounds detect by hazardous classification is provided in Figure 4.16.

Figure 4.16 Rubber products screening results



Three samples were identified as containing one of two phthalate groups which include classified phthalates (DINP/DHUNP, where DHUNP is classified as H360 and DEHP/DNOP/DIOP where DEHP and DIOP are classified as H360). Details of the three samples is provided in Table 4.94. Two samples were found to contain >100,000 mg/kg of these phthalate groups, with a third sample containing between 1,000 and 10,000 mg/kg. Since H360 has a hazardous threshold of 3,000 mg/kg for HP 10, toxic to reproduction, these samples may be hazardous depending on which phthalate is present.

Table 4.94 Rubber samples phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration bands (mg/kg)		HP threshold exceedance
		Chlorine	DINP/DHUNP	DEHP/DNO /DIOP	HP 10
1043	Other rubber products	198,664	>10,000	ND	Likely*
2042	Window/door seals	73,267	ND	>10,000	Likely*
5066	Window/door seals	26,255	ND	1,000 – 10,000	Possible*

4.8.4. Quantitative analysis

Sample selection

Of the eight-samples selected for screening, all were selected for at least one quantitative analysis suite. Justification for selection is provided in Table 4.95.

Table 4.95 Rubber products sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	0/51	No BFRs detected and rubber not identified as a likely source.
SCCPs and MCCPs	6/62	Due to the flexible property requirements of rubber, a total of six samples with a range of chlorine concentrations were selected.
Phthalate and UV-328	6/67	Phthalates known to be used in rubber products. Screening suggests low concentrations, so samples selected to verify screening data.
PFAS	1/20	One sample selected as a check from rubber category due to budgetary restrictions
OPFRs	0/20	Sample with hazardous OPFRs between 1,000 and 10,000 mg/kg.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.96.

Table 4.96 Rubber chlorinated paraffins quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
2042	Window/door seals	<500	<500
4008	Other seal/gasket	<600	<600
4104	Other rubber product	<500	<500
5038	Window/door seal	<600	14,200
5066	Window/door seal	<700	<700
R041	Window/door seal	<600	1,500

Note: Orange shading above LOQ, red shading hazardous property threshold exceeded

No SCCPs were identified in the quantitative analysis of the six rubber samples which was in line with the screening analysis.

Two samples were identified with MCCPs concentrations above the LOQ. Sample 5038 had a MCCPs concentration of 14,200 mg/kg (which was not identified in the screening). MCCPs are classified as H410, and this concentration is above the threshold for HP 14

(2,500 mg/kg). Sample R041 also contained MCCPs, but at levels below the hazardous thresholds on its own, but above the cut off threshold for H410 meaning it would be included as an additive concentration in the overall HP 14 assessment.

As MCCPs are proposed for listing under the Stockholm convention, The POPs status of these samples may change in the future.

Phthalates

Through quantitative analysis it was possible to further distinguish the phthalates present, with DINP (not classified) separated from DHUNP (classified as H360) and DNO (not classified) from DEHP/DIOP (classified as H360). It was not possible to distinguish DEHP from DIOP during analysis.

Table 4.97 shows the quantified phthalates detected above LOQ, including un-classified substances (in this case DINP and DIDP). The relatively high LOQs are discussed in Section 6.4.

Table 4.97 Rubber samples phthalate quantitative results

Sample	Category	Classified (hazard statement codes) (mg/kg)	Not classified (mg/kg)		
		DEHP/DIOP	DIDP	DINCH	DINP
1043	Other rubber products	<1800	92,060	<200	19,430
2042	Window/door seals	98,880	<1000	<200	<600
4104	Other rubber products	<1800	48,210	5,000	<600
5038	Window/door seals	<2100	1,230	<200	<600
5066	Window/door seals	<2500	1,590	<200	<800
R041	Other seals/gaskets	<2100	<800	<200	<700

The quantified analysis shows one sample exceeds the 3,000 mg/kg HP 360 threshold for HP 10 due to a concentration of DEHP/DIOP of 98,880 mg/kg. Sample 1043 in which the DINP/DHUNP phthalate group was detected during screening has been shown to contain the un-classified DINP, meaning it would not be classified as hazardous.

UV-328

UV-328 was not detected above the LOQ of 200 mg/kg in the six rubber samples sent for quantitative analysis.

PFAS

PFAS were not detected above the LOQ of 5µg/kg in the rubber sample sent for PFAS analysis.

4.8.5. Summary

The quantitative analysis of rubber products detected relatively little in the way of classified substances compared with other categories. One sample was found to have DEHP/DIOP (classified as H360) at concentrations of almost 100,000 mg/kg, exceeding the 3,000 mg/kg threshold for HP 10. Two samples were found to contain MCCPs, one with 14,200 mg/kg and the other with 1,500 mg/kg. The former exceeds the H410 threshold of 2,500 mg/kg for HP 14, and the latter exceeds the cut off limit and so would be included in the overall HP 14 assessment.

Table 4.98 summarises the results for the quantitative analysis of rubber products. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the waste stream as a whole. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Table 4.98 Summary of the prevalence of classified substances in rubber products

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Low	
MCCPs	Medium	Two samples contained MCCPs, one above the 2,500 mg/kg threshold for HP 14 and one below the threshold but above the cut off limit.
Classified BFRs	Low	
Classified phthalates	Medium	One sample contained DEHP/DIOP at a concentration in excess of the H360 hazard threshold of 3,000 mg/kg for HP 10.
Classified OPFRs	Low	

Zinc, which is likely to be present as zinc oxide, a known additive in rubber products to aid the vulcanisation process, was detected over concentrations of 2,500 mg/kg in 23% of samples collected. Since zinc oxide is classified as H410, these samples would exceed the HP 14 threshold. Table 4.99 summarises the relative prevalence of the key elements.

Table 4.99 Summary of key elements in rubber products

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	Low	
Zinc	High	Zinc was prevalent in rubber samples, with 23% of the samples collected containing concentrations of over 2,500 mg/kg from XRF scanning, exceeding the H410 hazardous threshold for HP 14.

Table 4.100 shows the number of samples within each category of rubber product where exceedances in threshold limits were observed. Zinc was present at relevant concentrations across all categories, although on a percentage basis was more prevalent in the “other seal/gasket” category.

Table 4.100 Rubber samples exceeding thresholds by category

Category	Total collected (n)	Samples exceeding hazardous property thresholds (n)			
		Quantitative		XRF	
		CPs	DEHP/DIOP	Lead	Zinc
Rubber products	62	1 (6)	1 (6)	1	15
Window/door seals	39	1 (4)	1 (4)	1	6
Other seals/gaskets	7	0 (1)	0 (1)	0	3
Other rubber products	16	0 (1)	0 (1)	0	6

4.9. Fixtures and Fittings

4.9.1. Sample collection

A total of 57 samples were collected under the fixtures and fittings category These samples collected were divided into ten further categories as outlined in Table 4.101.

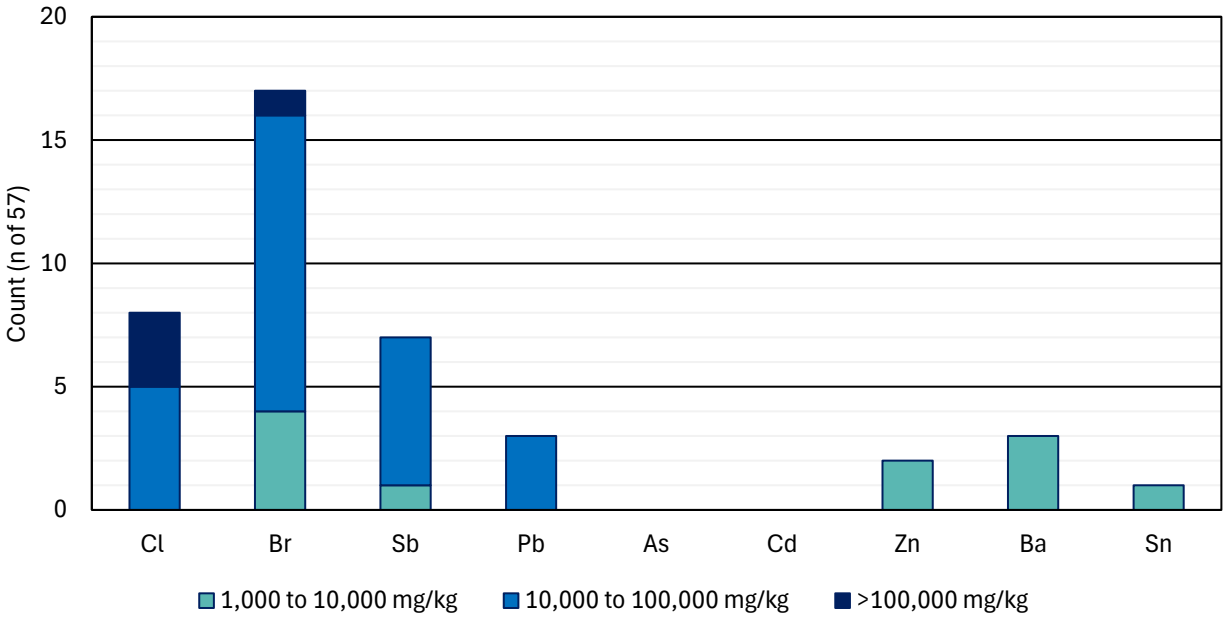
Table 4.101 Fixtures and fittings

Category	Count	Description
Sockets	16	UK three pin plug sockets, wall and floor mounts, predominantly white.
Switches	7	Electrical control equipment (e.g. temperature and lighting).
Cable covers	15	Materials/equipment for the grouping/covering of cables.
Safety controls	4	Alarm and electricals controls (e.g. fuse box and fire alarm).
Lighting	6	Light fittings.
Other fixtures and fittings	9	Other fixtures and fittings which do not fit the description of the other categories.

4.9.2. XRF scanning

Each collected sample underwent XRF scanning in triplicate. The range of target element concentrations recorded for the fixtures and fittings category are outlined in Figure 4.17.

Figure 4.17 Fixtures and fittings XRF results



Of the fixtures and fittings samples collected, 17 (30%) of samples were found to have a bromine concentration above 1,000 mg/kg, the highest proportion of all the C&D categories analysed. A total of 13 samples had a bromine concentration above 10,000 mg/kg and one sample had over 100,000 mg/kg bromine. This is indicative of the flame retardant requirements of these products.

Antimony was detected above 1,000 mg/kg in eight samples, seven of which had bromine present at above 10,000 mg/kg. These samples are shown in Table 4.102. The levels of antimony are greater in fixtures and fittings than any other category, likely due to the use of antimony trioxide as a synergist for brominated flame retardants in rigid plastics.

Table 4.102 Fixtures and fittings with antimony >1,000 mg/kg

Sample	Category	Antimony (mg/kg)	Bromine (mg/kg)
5056	Switches	80,860	75,832
4010	Sockets	43,567	44,962
3003	Other fixtures and fittings	18,387	10,410
4015	Switches	17,916	19,539
4021	Sockets	16,508	125,144
R037	Switches	16,120	7,2017
3056	Safety controls	1,482	730

Antimony trioxide is classified as H351 which has a hazardous threshold of 10,000 mg/kg threshold for HP 7, carcinogenic. It is therefore likely that six of these samples would exceed this threshold and be classified as hazardous with HP 7.

Three samples had a lead concentration above 10,000 mg/kg, with no samples containing between 1,000 and 10,000 mg/kg (Table 4.103). All these samples contained chlorine above 50,000 mg/kg, with two sample likely to be PVC with chlorine levels close to 200,000 mg/kg. These samples are detailed in Table 4.103.

Table 4.103 Fixture and fittings samples lead with >10,000 mg/kg

Sample	Category	Lead (mg/kg)	Chlorine (mg/kg)
5072	Other fixtures and fittings	23,515	58,138
4053	Sockets	22,981	196,183
4088	Cable covers	18,444	188,080

Lead (as lead compounds) is classified as H360 and H410 which have thresholds of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. Despite the semi-

quantitative nature of the handheld XRF scanning a concentration over 10,000 mg/kg means it is very likely these samples would be hazardous by both HP 10 and HP 14.

4.9.3. Chemical screening

Sample selection

A total of 21 fixtures and fittings samples were selected for screening, resulting in an over representation of this product (fixtures and fittings represented 5% of all samples taken but 11% of all samples sent for chemical screening). This was primarily due to the number of samples with high bromine (>1,000 mg/kg), likely present as BFRs due to their proximity to electronics. The breakdown of sample selection by category is provided in Table 4.104.

Table 4.104 Fixture and fitting sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Fixtures and fittings (all)	57	21
Sockets	16	7
Switches	7	6
Cable covers	15	2
Safety controls	4	1
Lighting	6	3
Other fixtures and fittings	9	2

Screening results – POPs

Of the six POPs compounds included in the screening list, none were detected.

No other substances proposed for listing under the Stockholm Convention (i.e. MCCPs) or substances the ECHA PBT list were also identified at any level from the screening test.

Screening results – classified substances

Of the 21 samples sent for screening analysis 12 were found to contain substances classified as hazardous. A breakdown of the compounds detect by hazardous classification is provided in Figure 4.18.

A total of seven samples were found to contain either TCP or TPP, two classified organophosphate flame retardants (OPFRs) above 10,000 mg/kg. Both substances are classified as H400 and H410, with TCP also classified as H361. It is therefore highly likely that all seven samples exceed the H410 threshold of 2,500 mg/kg for HP 14, ecotoxic. The two samples containing TCP may exceed the H361 threshold of 30,000 mg/kg for HP 10, toxic for reproduction, however this cannot be confirmed without quantitative analysis. These samples are detailed in Table 4.105.

Figure 4.18 Fixtures and fittings screening results

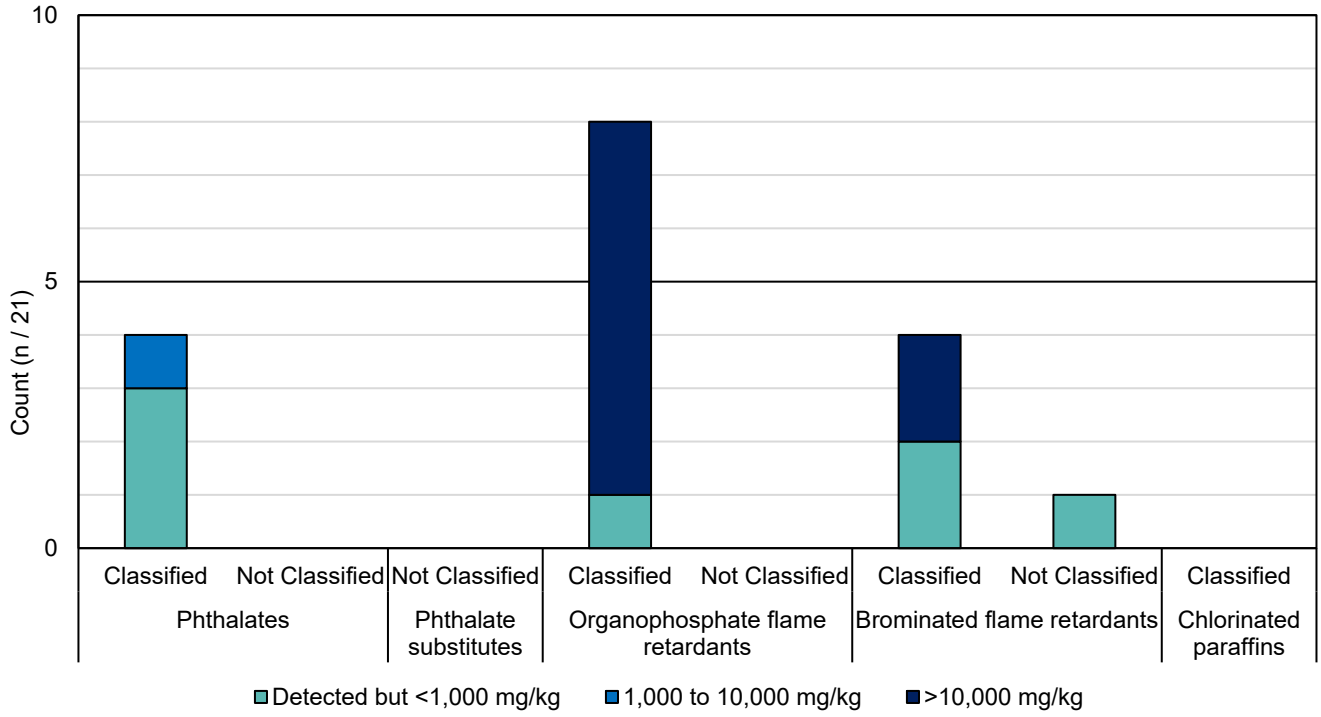


Table 4.105 Fixtures and fittings with classified OPFR detected >1,000 mg/kg

Sample	Category	Screening		HP threshold exceedance	
		TCP (mg/kg)	TPP (mg/kg)	HP 10	HP 14
3002	Other fixtures and fittings	<1,000	>10,000	Highly unlikely	Highly likely
3008	Lighting	ND	>10,000	N/A	Highly likely
3053	Switches	ND	>10,000	N/A	Highly likely
4013	Lighting	ND	>10,000	N/A	Highly likely
4027	Cable covers	>10,000	1,000 – 10,000	Possible	Highly likely
4034	Lighting	ND	>10,000	N/A	Highly likely
5060	Cable covers	>10,000	<1,000	Possible	Highly likely

Two additional samples were identified to contain the hazardous BFR TBBPA above 10,000 mg/kg. The two most stringent classifications for TBBPA are H350 and H410 which have hazardous thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg) respectively. Both samples would therefore have a TBBPA concentration in significant exceedance of both thresholds and would be classified as hazardous. The samples are detailed in Table 4.106.

Table 4.106 Fixtures and fittings with classified BFRS >1,000 mg/kg

Sample	Description	Screening concentration band (mg/kg)	HP threshold exceedance	
		TBBPA	HP 7	HP 14
4015	Switches	>10,000	Highly likely	Highly likely
4021	Sockets	>10,000	Highly likely	Highly likely

One sample which was identified to contain TCP above 10,000 mg/kg was also found to contain a phthalate group containing DEHP/DIOP. These substances are classified as H360, which have a hazardous threshold of 3,000 mg/kg for HP 10. Depending on the phthalate present, and the level it is present at, this may also lead to a HP 10 hazardous classification as well as the TCP concentration. This sample is detailed in Table 4.107.

Table 4.107 Fixtures and fittings phthalate screening results (classified substances >1,000 mg/kg)

Sample	Description	Screening concentration band (mg/kg)	HP threshold exceedance
		DEHP/DNOP/DIOP	HP 10
5060	Cable covers	1,000 – 10,000	Possible

4.9.4. Quantitative analysis

Sample Selection

Of the 21 samples selected for screening 17 were selected for at least one quantitative analysis suite. Justification for selection is provided in Table 4.108.

Table 4.108 Sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	16/51	Category of high interest for BFRs and XRF analysis indicated significant bromine content in several samples. One sample with TBBPA above 10,000 mg/kg and two with <1,000 mg/kg selected. The remaining samples were selected with a range of bromine and antimony concentrations from a range of sources.
SCCPs and MCCPs	4/62	Samples with a range of chlorine and antimony concentrations.
Phthalate and UV-328	1/67	One sample selected from fixture and fitting category as an example of this material.
PFAS	0/20	No samples selected as not identified as a likely source.
OPFRs	8/20	All samples identified to contain hazardous OPFRs above 1,000 mg/kg were selected.

Brominated flame retardants

The results of the quantitative BFR analysis are provided in Table 4.109. Of the 16 samples analysed two were found to contain BFRs above the LOQ.

Sample 4027 was found to have a combined POPs PBDE concentration of over 31,000 mg/kg, as the POPs threshold of the sum of these compounds is 500 mg/kg this sample significantly exceeds this threshold. Table 4.110 shows the concentrations of the individual PBDEs.

As penta-BDE is classified as H410 the HP 14 hazardous threshold of 2,500 mg/kg applies which the concentration in this sample exceeds. In the screening analysis no PBDE compounds were identified at any concentration in any fixture and fitting sample analysed, demonstrating a limitation in the chemical screening.

The TBBPA concentration in sample 4015 was 94,100 mg/kg. As TBBPA is classified as both H350 and H410 (most stringent) the hazardous thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg) would apply. This sample exceeds both limits.

It should be noted that the relatively high LOQs are due to high dilution rates used by the laboratory to protect instrumentation and prevent overwhelming the mass spectrometer. This is discussed in detail in Section 6.4.

Table 4.109 Fixtures and fittings BFR quantitative results

Sample	Category	XRF (mg/kg)		Classified POPs (mg/kg)		Classified (hazard statement codes) (mg/kg)
		Bromine	Antimony	tetra- to hepta-BDE	deca-BDE	TBBPA
3002	Other	14,370	18	<410	<130	<260
3008	Lighting	35,527	18	<480	<140	<290
3053	Switch	32,394	160	<440	<140	<270
3056	Safety control	730	1,482	<440	<130	<270
3113	Socket	67	18	<480	<150	<300
4010	Socket	44,962	43,567	<500	<150	<310
4013	Lighting	46,167	18	<650	<200	<400
4015	Switch	19,539	17,916	<500	<150	94,100
4021	Socket	125,144	16,508	<460	<140	<280
4027	Cable cover	52,485	18	31,220	<150	<300
4034	Lighting	40,749	18	<550	<170	<340
4056	Socket	14,913	143	<570	<180	<360
5040	Switch	1,198	18	<440	<130	<270
5056	Switch	75,832	80,859	<550	<170	<340
R037	Switch	72,017	16,120	<500	<150	<310
R038	Switch	1,740	18	<530	<160	<320

Note: Orange shading above LOQ, green above POPs threshold

Table 4.110 Fixtures and fittings PDBE breakdown

Sample	Category	Description	tetra-BDE (mg/kg)	penta-BDE (mg/kg)	hexa-BDE (mg/kg)	hepta-BDE (mg/kg)
4027	Cable Cover	Cable Velcro ties	12,800	16,900	1,490	30

Dechlorane plus

Dechlorane plus was not detected above the LOQ of between 70 and 80 mg/kg in any of the samples analysed.

Chlorinated paraffins

The results of the quantitative CPs analysis are provided Table 4.111.

Table 4.111 Fixtures and fittings chlorinated paraffin quantitative results

Sample	Category	SCCPs (mg/kg)	MCCPs (mg/kg)
3113	Socket	<600	<600
4021	Socket	<500	<500
4056	Socket	<600	<600
5072	Other fixture and fitting	<500	<500

No CPs were identified above the LOQ in the four fixtures and fittings samples analysed.

Phthalates

A single extension lead was sent for quantitative analysis testing. None of the phthalate compounds included in the test suite were identified above LOQ (variable). This matches the screening analysis.

UV-328

UV-328 was not identified above LOQ (200 mg/kg) in the single fixture and fitting sample sent for quantitative analysis.

Organophosphates

The results of the quantitative OPFRs analysis are provided in Table 4.112. As both TPP and TCP have a classification of H410 the cumulative hazardous threshold for HP 14 is 2,500 mg/kg. Therefore, seven of the eight samples analysed exceeded this threshold.

Excluding one cladding and wall panel sample, all the samples found to exceed hazardous thresholds from the quantitative analysis of OPFRs were in the fixtures and fittings category.

Table 4.112 Fixtures and fittings organophosphate quantitative results

Sample	Category	TCP (mg/kg)	TPP (mg/kg)
3002	Other fixture and fitting	270	66,510
3008	Lighting	<40	31,940
3053	Switch	<40	39,380
3056	Safety control	<40	<35
4013	Lighting	350	49,900
4027	Cable cover	9,900	6,805
4034	Lighting	730	43,290
5060	Cable cover	10,380	3,680

Note: Orange shading above LOQ, red shading hazardous property threshold exceeded

4.9.5. Summary

Despite the fixtures and fittings category containing the greatest number of samples with over 1,000 mg/kg bromine detected during XRF scanning (30% of samples), BFRs were only quantified in two of the 16 samples submitted for quantitative analysis above the LOQ.

Of these, one had a PBDE concentration of over 30,000 mg/kg. This was primarily from tetra-BDE and penta-BDE. This sample therefore contained PBDEs far in exceedance of the 500 mg/kg POPs threshold. The second sample contained TBBPA at almost 100,000 mg/kg, which greatly exceeds the H350 hazardous threshold of 1,000 mg/kg for HP 7 and the H410 hazardous threshold of 2,500 mg/kg for HP 14.

Although BFRs did not have a high prevalence, OPFRs were present in significant concentrations (over 10,000 mg/kg) in seven samples. OPFRs are therefore of particular importance in this C&D category. The OPFRs quantified were classified as H410, and these seven samples far exceed the hazardous threshold of 2,500 mg/kg for HP 14.

Table 4.113 summarises the results for the quantitative analysis of fixtures and fittings. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the whole waste stream. It can however provide an indication of the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Antimony was detected in fixtures and fittings at higher levels than in any other category. Since this was typically alongside elevated bromine it would be reasonable to assume it was present as antimony trioxide. Antimony trioxide is classified as H351 with a threshold of 10,000 mg/kg for HP 7. Despite this relatively high threshold, six samples were found with concentrations exceeding this through XRF scanning. Table 4.114 summarises the relative prevalence of the key elements.

Table 4.113 Summary of the prevalence of classified substances in fixtures and fittings

Substance	Relative prevalence	Commentary
deca-BDE		
tetra- to hepta-BDE	Medium	The only sample where PBDEs other than deca-BDE were detected was in the fixtures and fittings category, where the sample had a concentration far exceeding the POPs threshold.
HBCD		
Dechlorane plus		
UV-328		
SCCPs		
MCCPs	Low	
Classified BFRs	Medium	Despite the bromine and antimony concentrations indicating BFRs, only one sample (aside from the sample with PBDES) had BFRs quantified above the LOQ. This sample contained TBBPA at almost 100,000 mg/kg, far exceeding the HP 7 and HP 14 thresholds for the associated hazard statement codes.
Classified phthalates	Low	
Classified OPFRs	High	Based on this study OPFRs are relatively abundant in fixtures and fittings, with concentrations in seven samples above 10,000 mg/kg.

Table 4.114 Summary of key elements in fixtures and fittings

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	High	Antimony, likely present as antimony trioxide as present in seven sample at concentrations over 10,000 mg/kg (as determined through XRF scanning). This samples exceeds the H351 threshold for HP 7.
Lead	Low	
Zinc	Low	

Table 4.115 shows the number of samples within each category where exceedances in threshold limits were observed.

Table 4.115 Fixtures and fitting samples above threshold

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)					
		Quantitative	Quantitative				XRF	
		PBDEs	PBDEs	TBBPA	TPP	TCP	Lead	Zinc
Fixtures and Fittings (all)	57	1 (16)	1 (16)	1 (16)	7(8)	2 (8)	3	1
Sockets	16	0 (4)	0 (4)	0 (4)	-	-	1	0
Switches	7	0 (6)	0 (6)	1 (6)	1 (1)	0 (1)	0	0
Cable covers	15	1 (1)	1 (1)	0 (1)	1 (2)	2 (2)	1	0
Safety controls	4	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0	0
Lighting	6	0 (3)	0 (3)	0 (3)	3 (3)	0 (3)	0	0
Other fixtures and fittings	9	0 (1)	0 (1)	0 (1)	1 (1)	0 (1)	1	1

4.10. Discarded Construction Materials

4.10.1. Sample collection

A total of 45 discarded construction materials were collected during sampling. The samples collected were divided into ten categories as outlined in Table 4.116.

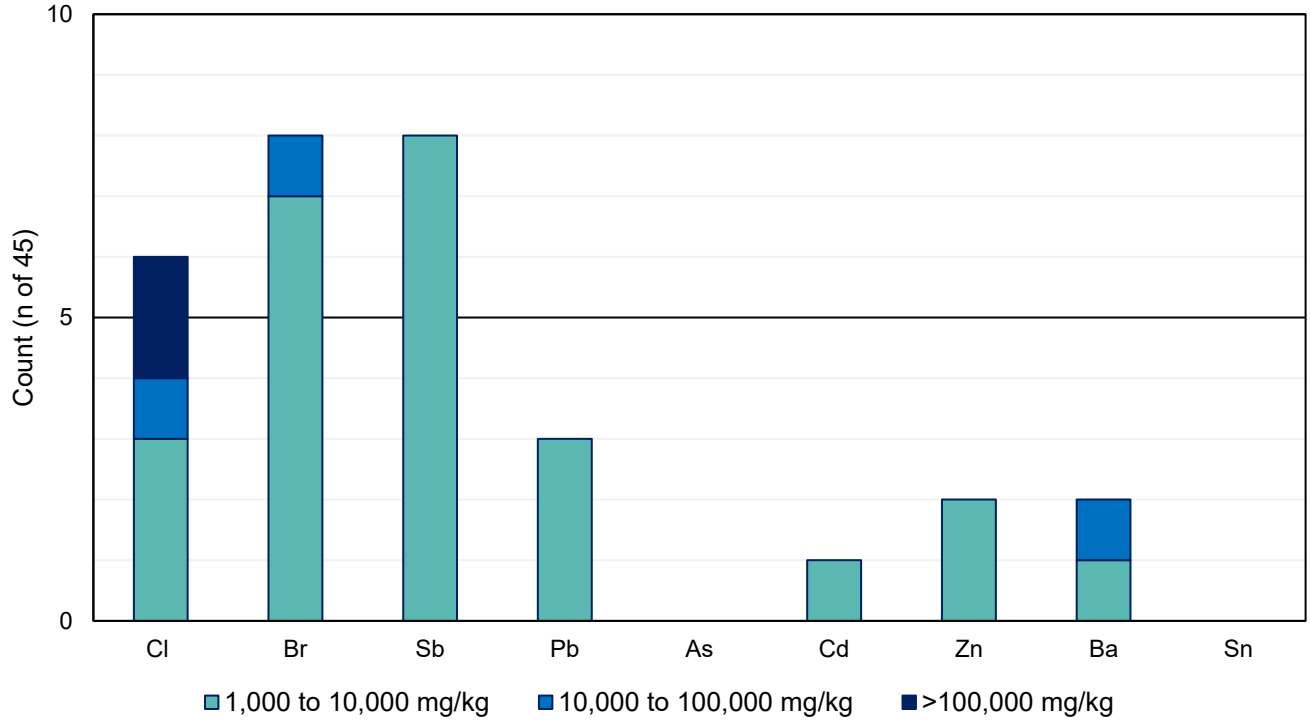
Table 4.116 Discarded construction materials

Category	Count	Description
Packaging	3	Material used to contain/store newly purchased building material/equipment.
Temporary flooring	18	Thin plastic sheeting used to protect floors during construction work, often corrugated and black.
Chemical containers	12	Bottles and buckets that previous contained construction chemical (e.g. sealant tube).
Equipment	12	Items used during the C&D process (e.g. buckets, traffic cones, barriers etc.)

4.10.2. XRF scanning

Each collected sample underwent XRF scanning in triplicate. The range of target element concentrations recorded for the insulation category is outlined in Figure 4.19.

Figure 4.19 Discarded construction materials XRF results



Of the samples collected eight were found to contain bromine above 1,000 mg/kg, one of which had bromine over 10,000 mg/kg. Aside from the sample with the lowest bromine content (1069 – a traffic cone), all samples were categorised as temporary flooring. Antimony was also detected in all but one of the eight samples at levels over 1,000 mg/kg. The levels of antimony detected indicated that the bromine was present as brominated flame retardants (BFRs). Discarded construction materials with bromine >1000 mg/kg are detailed in Table 4.117.

Table 4.117 Discarded construction materials with bromine >1,000 mg/kg

Sample	Category	Bromine (mg/kg)	Antimony (mg/kg)
2086	Temporary flooring	21,902	7,670
4095	Temporary flooring	8,107	3,802
3092	Temporary flooring	7,963	2,800
1240	Temporary flooring	7,611	2,419
2078	Temporary flooring	6,285	2,116
2148	Temporary flooring	3,634	1,001
R062	Temporary flooring	1,311	229
1069	Equipment	1,170	5,754

Antimony is likely to be present as antimony trioxide, a synergist to improve flame retardancy. Antimony trioxide is classified as H351 with a HP 7, carcinogenic, threshold of 10,000 mg/kg. It is therefore likely that one sample exceeds this threshold and could be classified as hazardous with HP 7.

Three samples, including sample 1069 discussed above (a traffic cone), contained lead at levels over 1,000 mg/kg. These samples are shown in Table 4.118.

Table 4.118 Discarded construction equipment with lead >1,000 mg/kg

Sample	Category	Lead (mg/kg)	Bromine (mg/kg)	Chlorine (mg/kg)	Antimony (mg/kg)
1210	Equipment	9,649	772	157,108	8,350
2141	Temporary flooring	4,440	1	360	18
1069	Equipment	4,211	1170	92,382	5,754

The two equipment samples (1069 – traffic cone and 1210 – barrier stand), are typically made from post-consumer PVC waste, including cable granulate, which explains the lead and chlorine content, as lead has historically been used as a stabiliser in PVC. Lead (as lead compounds) is classified as H360 and H410 and has thresholds of 3,000 mg/kg for HP 10 and 2,500 mg/kg for HP 14 respectively. It is possible therefore that these three

samples could be classified as hazardous with both HP 10, carcinogenic, and HP 14, ecotoxic.

4.10.3. Chemical screening

Sample selection

A total of 11 samples were selected for screening, resulting in slight over representation of this product (discarded construction materials represented 4% of all samples taken but 6% of all samples sent for chemical screening). This was due to the levels of bromine and antimony detected during XRF analysis. The breakdown of sample selection by category is provided in Table 4.119.

Table 4.119 Discarded construction sample selection for chemical screening

Category	Total collected (n)	Total for screening (n)
Discarded construction materials (all)	45	11
Packaging	3	0
Temporary flooring	18	6
Chemical container	12	1
Equipment	12	4

Screening results – POPs

Of the six POPs compounds included in the screening list only SCCPs were detected. The details of the samples containing these compounds are provided in Table 4.120.

Table 4.120 Discarded construction material POPs screening results

Sample	Category	XRF analysis (mg/kg)			Screening concentration bands (mg/kg)
		Bromine	Antimony	Chlorine	SCCPs
1069	Equipment	1,170	5,754	92,382	1,000 – 10,000
1210	Equipment	772	8,350	157,108	1,000 – 10,000

SCCPS were detected with a concentration of between 1,000 and 10,000 mg/kg in two samples (1069 – traffic cone and 1210 – barrier stand), both of which appeared to be made of low-quality recycled plastic. A picture of both samples is provided in Photograph 4.4. These samples were those identified with high lead content during XRF scanning.

Photograph 4.44 Sample 1069 (left) and 1210 (right)

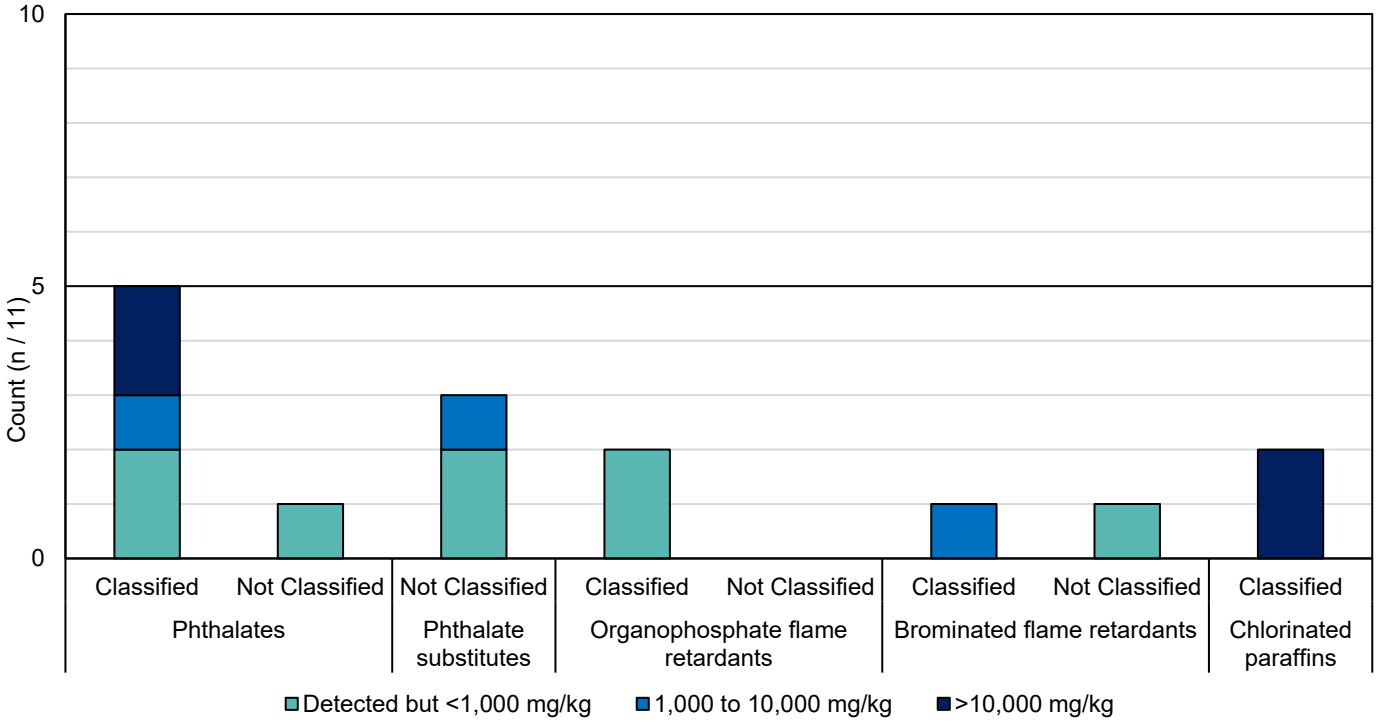
As the upper threshold for this concentration band is the current POPs threshold of SCCPs (10,000 mg/kg) the sample likely does not exceed this threshold, but it may exceed a proposed future threshold (1,500 mg/kg). Both samples were also found the have a MCCPs concentration over 10,000 mg/kg. As MCCPs are proposed for listing under the Stockholm convention, the POPs classification of these samples may change in the future.

Sample 1069 was also found to contain TOTM (Tris(2-ethylhexyl) benzene-1,2,4-tricarboxylate) between 1,000 and 10,000 mg/kg. TOTM is a phthalate substitute and is under assessment by ECHA as persistent, bioaccumulative and toxic (PBT) and endocrine disrupting (ED). TOTM is not classified with any hazardous statement codes.

Screening results – classified substances

Of the 11 samples sent for screening analysis seven were found to contain compounds classified as hazardous A breakdown of the compounds detect by hazardous classification is provided in Figure 4.20.

Figure 4.20 Discarded construction materials screening results



MCCPs are classified as H410 which has a threshold of 2,500 mg/kg for HP 14. The two samples (1069 1210) identified to contain MCCPs above 10,000 mg/kg would therefore both exceed this threshold.

Both of these samples were also identified to contain two groups of phthalates (DINP/DHUNP and DEHP/DNOP/DIOP) which included phthalates (DHUNP and DEHP/DIOP respectively) classified as H360 at levels above 10,000 mg/kg. A third sample (also a traffic cone) contained DEHP/DNOP/DIOP at between 1,000 and 10,000 mg/kg. It is therefore possible that these samples exceed the H360 threshold of 3,000 mg/kg for HP 10, toxic for reproduction, depending on the phthalate present. The phthalate screening data with classified substances >1000 mg/kg are provided in Table 4.121.

Table 4.121 Discarded construction materials phthalate screening results (classified substances >1,000 mg/kg)

Sample	Category	XRF (mg/kg)	Screening concentration bands (mg/kg)		HP threshold exceedance
		Chlorine	DINP/ DHUNP	DEHP/DNOP/ DIOP	HP 10
1069	Equipment	92,382	>10,000	>10,000	Likely*
1210	Equipment	157,108	>10,000	>10,000	Likely*
1180	Equipment	126,174	ND	1,000 – 10,000	Possible*

*Higher likelihood cannot be concluded since the phthalate present may be the un-classified substance in the group.

One sample (4095 – temporary flooring) was found to contain between 1,000 and 10,000 mg/kg TBBPA. The two most stringent classifications for TBBPA are H350 and H410 which have hazardous thresholds for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg) respectively, making it possible the sample exceeded both thresholds and would be classified as hazardous with HP 7, carcinogenic, and HP 14, ecotoxic.

4.10.4. Quantitative analysis

Sample Selection

Of the 11-samples selected for screening, six were selected for at least one quantitative analysis suite. Justification for selection is provided in Table 4.122.

Table 4.122 Discarded Construction Materials sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	4/51	Sample with elevated bromine including a sample identified to contain TBBPA between 1,000 and 10,000 mg/kg.
SCCPs and MCCPs	2/62	Both samples identified to contain CPs.
Phthalate andUV-328	2/67	One of the two sample with phthalate above 10,000 mg/kg selected along with a temporary flooring sample.
PFAS	0/20	No samples selected as this category was not identified as a likely source and limited analytical capacity.
OPFRs	0/20	No samples identified to contain OPFRs above 1,000 mg/kg.

Brominated flame retardants

The results of the quantitative BFR analysis are provided in Table 4.123 for samples where BFRs were quantified above the LOQ.

Table 4.123 Discarded construction materials brominated flame retardant results

Sample	Category	Classified (hazard statement codes) (mg/kg)	Non-Classified (mg/kg)
		TBBPA	TBBPA-BDBPE
1069	Equipment	<310	<170
1240	Temporary flooring	<310	30,100
2148	Temporary flooring	<330	18,800
4095	Temporary flooring	2,400	39,200

The two BFR compounds detected above LOQ in at least one sample were TBBPA-BDBPE and TBBPA. TBBPA-BDBPE has no associated hazardous classification, but TBBPA has multiple classifications, the most stringent of which are H350 and H410 which have hazardous threshold for HP 7 (1,000 mg/kg) and HP 14 (2,500 mg/kg). Sample 4095 would therefore exceed the HP 7 threshold but fall just below the HP 14 threshold. It is however above the contribution threshold of 1,000 mg/kg and therefore would be included in the overall HP 14 assessment.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.124

Table 4.124

Table 4.124 Discarded construction materials chlorinated paraffins results

Sample	Description	SCCPs (mg/kg)	MCCPs (mg/kg)
1069	Equipment	<5,200	81,400
1210	Equipment	<5,300	37,000

No SCCPs were identified above LOQ in either sample. However, the dilution required to analyse both samples was much higher than any other sent for CPs analysis, resulting in a relatively high LOQ. This is due to multiple contaminants in these products which are high in post-consumer recyclate (further details are provided in Section 6.4). This LOQ is below the current POPs threshold for SCCPs of 10,000 mg/kg but above a possible future threshold of 1,500 mg/kg.

MCCPs are classified as H410 which has a hazardous threshold of 2,500 mg/kg for HP 14. As both samples have a MCCPs concentration above 35,000 mg/kg they would therefore exceed this threshold.

As SCCPs are also classed as H410 the elevated LOQ obstructs completion of the HP assessment as it is unclear whether these samples would also contribute to the HP 14 assessment, however it does not change the fundamental outcome.

Phthalates

No phthalates classified with hazard statement codes were detected in either sample analysed (1069 and R0620) above the LOQ. However, the LOQ for sample 1069 (the traffic cone made from post-consumer recyclate) is high for several phthalates. This is because the sample had to be diluted to a high level due to the number of substances present effecting the analysis. The results are given in Table 4.125.

Table 4.125 Discarded construction materials phthalate quantitative results

Sample	Description	Classified (hazard statement codes) (mg/kg)	Not classified (mg/kg)		
		DEHP/DIOP	DIDP	DINCH	DINP
1069	Equipment	<19,000	34,910	<1,450	<5,780
R062	Temporary flooring	<2,300	<900	<200	<700

The LOQ of DEHP/DIOP for sample 1069 was 19,000 mg/kg. As both compounds are classified as H360 they have an individual HP 10 threshold of 3,000 mg/kg. As DNOP was found to be <400 mg/kg and the screening data of the phthalate group DEHP/DNOP/DIOP was found to be above 10,000 mg/kg this would indicate a likely exceedance of the HP 10 hazardous threshold. Additionally, as the LOQ for DINP is 5,780 mg/kg and as the sample was found to have the screening result for the DINP/DHUNP above 10,000 mg/kg this would indicate a DHUNP concentration of at least 4,000 mg/kg. As DHUNP is classified as H360 this would put the concentration above the HP 10 hazardous threshold of 3,000 mg/kg. However, DHUNP was not included in the quantification suite.

UV-328

UV-328 was not identified above the LOQ in either sample sent for quantitative analysis. As the traffic cone (sample 1069) had to be further diluted due to the elevated concentration of some compounds within the sample the LOQ is 1,450 mg/kg while the temporary flooring sample underwent the standard dilution and has a LOQ of 200 mg/kg. The required further dilution of some samples may have impacted the effectiveness of POPs testing especially with stringent thresholds.

4.10.5. Summary

Discarded construction materials is a difficult category to summarise as it contains a wide variety of products. The three products shown to be of particular interest were a traffic cone, barrier stand and temporary flooring. Cones and barrier stands are typically made from post-consumer PVC cable granulate and other post-consumer waste not suitable for more advance mechanical recycling. As such, they could contain a very wide range of substances.

Due to the high levels of interference in the cone and barrier stand material, extracts were diluted in a ratio of 1 to 10,000, resulting in high LOQs which often exceeded hazard statement codes HP thresholds. A true assessment of these products is therefore not possible with the current data set. This is especially true for phthalates and CPs, with an SCCPs LOQ of over 5,000 mg/kg.

Issues of dilution aside, two of these products were found to contain MCCPs at concentrations of 37,000 mg/kg and 81,400 mg/kg, far exceeding the H410 threshold of 2,500 mg/kg for HP 14. It also means that these kinds of products would be likely to

exceed a future MCCPs POPs limit if this substance is listed under the Stockholm convention.

There were three samples of temporary flooring and a disposable corrugated board material, which contained BFRs at concentrations over 10,000 mg/kg. All three contained TBBPA-BDBPE, which is not classified with any hazard statement codes, however one of these samples also contained TBBPA at 2,400 mg/kg. TBBPA is classified as H350 and H410, and so this exceeds the HP 7 threshold of 1,000 mg/kg and is close to the HP 14 threshold of 2,500 mg/kg. These products can be sold and marketed as being flame retardant so the presence of BFRs is understandable.

Table 4.126 summarises the results for the quantitative analysis of discarded construction equipment. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the waste stream as a whole. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Table 4.126 Summary of the prevalence of classified substances in discarded construction materials

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	Medium	SCCPs may be present in products made from recycled cable granule, but due to high LOQs quantification below a potential future threshold of 1,500 mg/kg was not possible.
MCCPs	Medium	MCCPs are likely to be present at concentrations over 10,000 mg/kg in products made from recycled cable granulate.
Classified BFRs	Medium	Flame retardants are used in disposable boards which can be used as temporary flooring (or wall covers). Only one sample was found to contain a BFR with hazard statement codes above the relevant HP thresholds.
Classified phthalates	Low	
Classified OPFRs	Low	

Antimony was detected in seven of the temporary flooring samples below 10,000 mg/kg and therefore below the relevant HP thresholds for the H351 hazard statement code for which antimony trioxide is classified. Lead was also found to be present in the products made with recycled cable granulate, which is expected since lead was used as a stabiliser in these products originally.

These two types of products, cones and bases made from recycled cable granule and boards for temporary flooring, stand out in this category, and if assessed in isolation would be assigned a high priority for SCCPs and MCCPs and lead in the former and BFRs and in the latter. A summary of key elements in discarded construction materials is provided in Table 4.127.

Table 4.127 Summary of key elements in discarded construction materials

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Medium	Present in seven samples above 1,000 mg/kg, mostly in disposable board products, but was below the 10,000 mg/kg H351 threshold for HP 7 for antimony trioxide.
Lead	Medium	Lead was present above the H360 and H3410 thresholds of 3,000 mg/kg and 2,500 mg/kg for HP 10 and HP 14 in three samples, two of which are believed to be made from recycled cable granulate.
Zinc	Low	

Table 4.128 shows the number of samples within each category where exceedances in threshold limits were observed.

Table 4.128 Discarded construction materials that exceed threshold

Category	Total collected (n)	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)		
		Quantitative	Quantitative		XRF
		SCCPs	TBBPA	CPs	Lead
Discarded construction materials	45	0 (2)	1 (4)	2 (2)	
Packaging	3	-	0 (1)	-	
Temporary flooring	18	-	-	-	1
Chemical containers	12	-	-	-	
Equipment	12	0* (2)	1 (3)	2 (2)	2

*Two heavily diluted samples with LOQ above potential future limit of 1,500 mg/kg.

4.11. Expanding Fillers

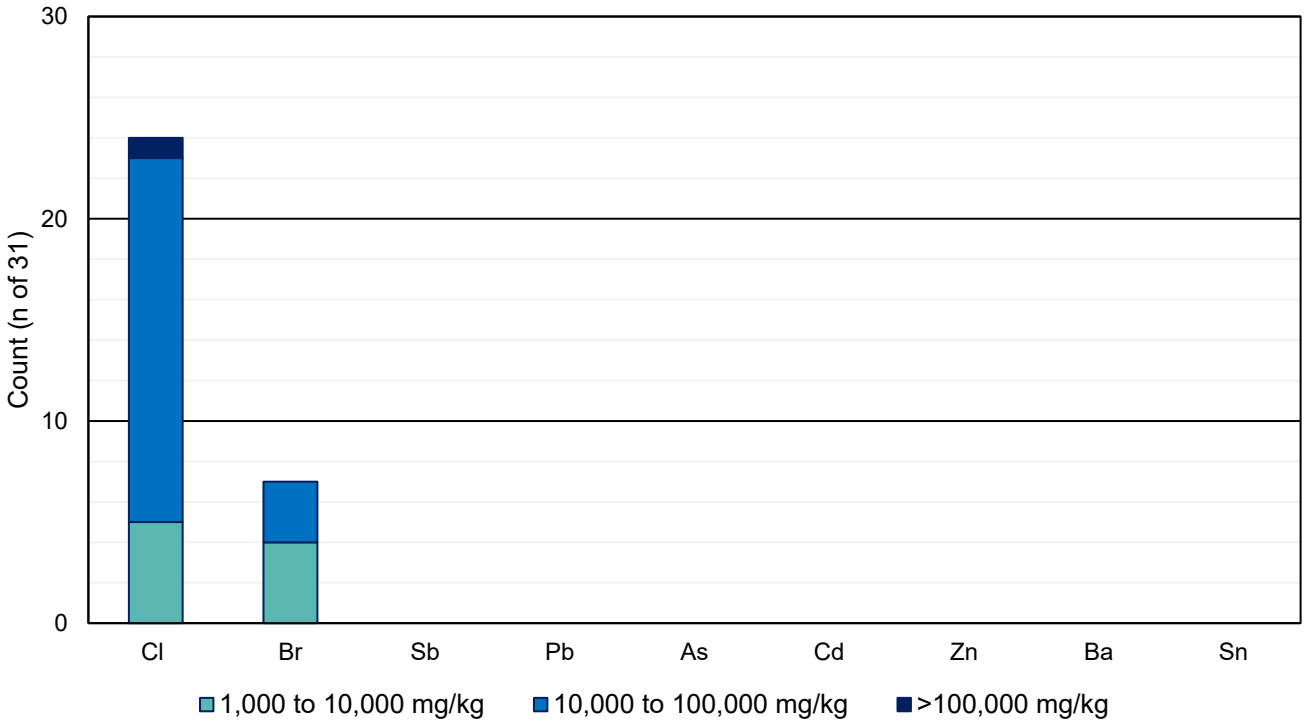
4.11.1. Sample collection

A total of 31 samples were collected of expanding fillers. Expanding fillers may have a range of ingredients, with some being a composite of polyurethane and isocyanate, which when combined react and harden. As all samples collected had very similar characteristics they have not been divided into sub-categories. Samples were predominantly a brittle low-density foam often yellow/orange or cream in colour.

4.11.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded in the adhesive and sealant category are outlined in Figure 4.21

Figure 4.21 Expanding fillers XRF results



XRF scanning identified seven samples that contained bromine above 1,000 mg/kg, of which three had a concentration above 10,000 mg/kg. No samples were found to have antimony above the LOD.

Chlorine was present in 24 samples (77%) above 1,000 mg/kg with the majority (19) being above 10,000mg/kg (61%). This is to be expected due to the known current use of chlorinated paraffins (CPs) in the manufacturing of expanding filler products.

Due to the low-density nature of this waste stream even with compression of the sample there is likely to be a reduced signal during XRF scanning, increasing the potential for an underestimation in elemental composition. It is therefore considered possible that elements such as antimony, zinc and lead may also be present.

4.11.3. Chemical Screening

Sample selection

A total of 10 expanding filler samples were selected for chemical screening resulting in slight over representation of this product (expanding fillers represented 3% of all samples taken but 5% of all samples sent for chemical screening). Expanding fillers were a stream of higher interest, predominantly due to their known use of CPs in manufacturing, however, the availability of these waste samples was extremely limited at many of the sites visited.

Screening results – POPs

Of the six POPs compounds included in the screening list SCCPs were detected in four samples. Table 4.129 outlines the details of each sample.

Table 4.129 Expanding filler POPs screening results

Sample	Description	XRF (mg/kg)			Screening concentration bands (mg/kg)
		Bromine	Antimony	Chlorine	SCCPs
N10	Gap expanding filler	69	<18	107,546	>10,000
N11	Heavy duty expanding filler	91	<18	80,650	1,000 – 10,000
R035	Expanding filler	1,411	<18	30,954	1,000 – 10,000
6015	Expanding filler	33	<18	32,767	1,000 – 10,000

For a single sample (N10) SCCPs were identified above 10,000 mg/kg, and therefore it is possible this sample exceeds the POPs threshold of 10,000 mg/kg. This sample was a new product purchased for this project from an online retailer.

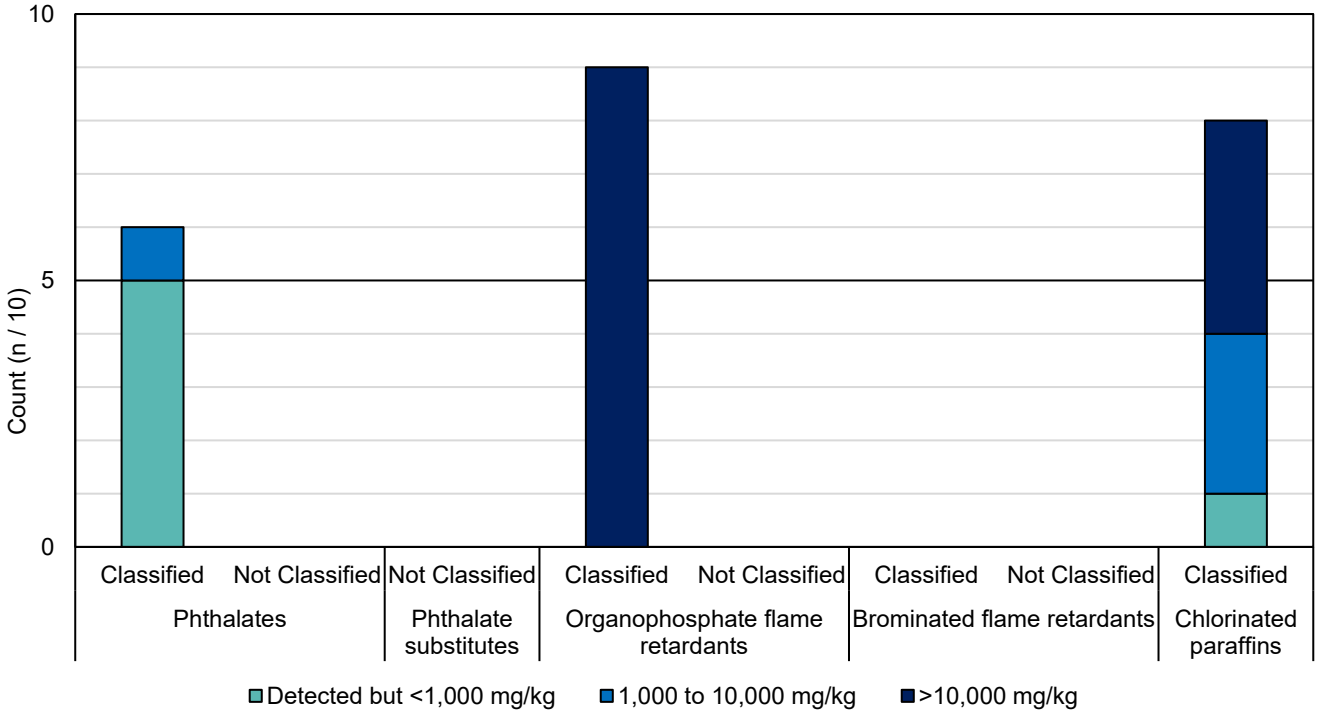
The concentration of SCCPs was found to be between 1,000 and 10,000 mg/kg in three other samples. These would therefore likely not exceed the current POPs threshold but may be above a future POPs threshold of 1,500 mg/kg. MCCPs were detected in these three samples and one other, as discussed in the section below.

No other sample was found to contain POPs, substances proposed for listing under the Stockholm convention or persistent, bioaccumulative and toxic (PBT) compounds.

Screening results – classified substances

Of the ten samples analysed, compounds with hazardous classifications were detected in eight samples. A breakdown of the compounds detect by hazardous classification is provided in Figure 4.22.

Figure 4.22 Expanding filler screening results



MCCPs are classified as H410 with a hazardous threshold of 2,500 mg/kg for HP 14 - ecotoxic and SCCPs are also classified as both H410 and H351 which has a threshold of 10,000 mg/kg for HP 7, carcinogenic. Table 4.130 shows the samples with greater than 1,000 mg/kg CPs detected during screening.

Table 4.130 Expanding fillers CPs screening results (classified substances >1,000 mg/kg)

Sample	Description	XRF (mg/kg)	Screening concentration band (mg/kg)		HP threshold exceedance	
		Chlorine	SCCPs	MCCPs	HP 7	HP 14
3063	Expanding filler from a fire door	480	N/D	>10,000	Unlikely	Highly likely
3073	Expanding filler from a window frame	1,428	N/D	1000 – 10,000	Unlikely	Possible
2195	Expanding filler	67,294	N/D	>10,000	Unlikely	Highly likely
N10	Expanding filler	107,546	>10,000	1000 – 10,000	Possible	Highly likely
N11	Expanding filler	80,650	1000 – 10,000	>10,000	Unlikely	Highly likely
R035	Expanding filler	30,954	1000 – 10,000	>10,000	Unlikely	Highly likely
6015	Expanding filler	32,767	1000 – 10,000	>10,000	Unlikely	Highly likely

Based on the screening data, it is highly likely that six samples, two of which were purchased new (N10 and N11), would be classified as hazardous by HP 14 ecotoxic. One of these (N10) may also exceed the H351 threshold of 10,000 mg/kg for HP 7 and would therefore also be classified as carcinogenic. An additional sample (3073) potentially contains MCCPs above the H410 threshold for HP 14, but this cannot be confirmed without quantitative analysis.

As MCCPs are proposed for listing under the Stockholm convention they could contribute to a CPs POPs exceedance of these samples in the future. One of these samples (N11) was purchased new for this project.

A single sample (6051) was found to contain a phthalate group which includes classified substances DEHP and DIOP between 1,000 and 10,000 mg/kg. These phthalates are classified as H360 and have a hazardous threshold of 3,000 mg/kg for HP 10, toxic for reproduction. This sample may therefore possibly exceed this threshold, however without knowing the exact phthalate present or the level, no further conclusions can be drawn.

A classified organophosphate flame retardant (OPFR), TCPP, was detected in nine samples above 10,000 mg/kg (no samples were found to contain between 10,000 and 100,000 mg/kg). TCPP is classified as H302, H351 and H412[11] with respective hazardous thresholds of 250,000 mg/kg for HP 6, acute toxicity, 10,000 mg/kg for HP 7, carcinogenic and 250,000 mg/kg for HP 14, ecotoxic. Table 4.131 shows the details of the nine samples.

[11] There is no harmonized classification for TCPP. Some entries include H361 but these are less numerous

Table 4.131 Expanding fillers with organophosphate flame retardants detected >1,000 mg/kg

Sample	Description	Screening concentration band (mg/kg)	HP threshold exceedance		
		TCPP	HP 6	HP 7	HP 14
1217	Expanding filler	>10,000	Unlikely	Likely	Unlikely
3063	Expanding filler from a fire door	>10,000	Unlikely	Likely	Unlikely
3073	Expanding filler from a window frame	>10,000	Unlikely	Likely	Unlikely
3076	Expanding filler	>10,000	Unlikely	Likely	Unlikely
3083	Expanding filler	>10,000	Unlikely	Likely	Unlikely
N10	Expanding filler	>10,000	Unlikely	Likely	Unlikely
N11	Expanding filler	>10,000	Unlikely	Likely	Unlikely
R035	Expanding filler	>10,000	Unlikely	Likely	Unlikely
6015	Expanding filler	>10,000	Unlikely	Likely	Unlikely

Screening detected over 10,000 mg/kg TCPP in all nine samples, which suggests that all samples are likely to exceed the threshold for HP 7, however due to the high thresholds for HP 6 and HP 14 they are unlikely to exceed these.

4.11.4. Quantitative analysis

Sample Selection

All ten samples selected for screening were submitted for at least one quantitative analysis suite. Justification for this selection is provided in Table 4.132.

Table 4.132 Expanding fillers sample selection for quantitative analysis

Testing suite	Count	Justification
BFRs and DCP	6/51	No BFRs detected but samples with elevated bromine were selected as a possible indicator they may be present.
SCCPs and MCCPs	9/62	All samples where CPs were detected along with a sample with elevated chlorine to increase the robustness of the assessment.
Phthalate and UV-328	3/67	Three samples with classified phthalates detected in screening.
PFAS	0/20	Not identified as a likely source
OPFRs	5/20	A number of samples where TCPP was identified above 10,000 mg/kg were selected.

Brominated flame retardants

Only a single unclassified flame retardant, BEHTBP, was identified above the LOQ in two of the six samples analysed (3063 and R035) with a concentration of 1,670 mg/kg and 1,610 mg/kg respectively.

Dechlorane plus

Dechlorane plus was not detected above the LOQ of between 70 and 80 mg/kg in any of the samples analysed.

Chlorinated paraffins

The results of the quantitative CP analysis are provided in Table 4.133.

A single sample (N10) had a SCCPs concentration above current POPs threshold (10,000 mg/kg). This is the highest quantitative SCCPs results of any sample selected., and was a sample purchased new for this project. As SCCPS and MCCPs have a hazardous classification of H410 which has a HP 14 hazardous threshold of 2,500 mg/kg this sample would exceed this threshold due to both SCCPs and MCCPs. SCCPs are also classified as H351 with a threshold of 10,000 mg/kg for HP 7, carcinogenic which this sample also exceeds.

Three other samples were found to contain SCCPs below the current POPs threshold but above a potential future threshold of 1,500 mg/kg. Three of the four samples with elevated SCCPs were above the hazardous threshold solely by SCCPs. All three samples also contained MCCPs above 150,000 mg/kg and therefore would exceed the combined H410 threshold of 2,500 mg/kg for HP 14.

Table 4.133 Expanding fillers chlorinated paraffins quantitative results

Sample	Description	SCCPs (mg/kg)	MCCPs (mg/kg)
1217	Expanding filler	<100	450
3063	Expanding filler from fire door	<500	195,000
3073	Expanding filler from window	<600	2,200
3083	Expanding filler	<700	4,700
2195	Expanding filler	<600	344,500
N10	Expanding filler	52,900	6,200
N11	Expanding filler	1,600	200,600
R035	Expanding filler	2,800	152,870
6015	Expanding filler	3,600	413,830

Note: Orange shading above LOQ, red shading hazardous property threshold exceeded

Of the five remaining samples with MCCPs detected but with SCCPs below the LOQ, two had concentrations over 100,000 mg/kg and a third with 4,700 mg/kg, resulting in all three samples exceeding the H410 threshold for HP 14.

MCCPs are proposed for listing under the Stockholm convention, and if they are listed as a POP, it would have a significant effect on the exceedance rate for expanding fillers, depending on the threshold implemented.

Phthalates

Of the three samples quantified for phthalates, only DIDP, an unclassified phthalate, was quantified above the LOQ in sample 6015 despite the screening only indicating DEHP/DIOP/DNOP between 1,000 and 10,000 mg/kg in sample. However, the LOQ is relatively high for phthalates (as discussed in Section 6.4 with and the LOQ for DEHP/DIOP of 2,600 mg/kg is also elevated in this sample, meaning one of these phthalates may be present below this concentration. As the hazardous limit for these substances is 3,000 mg/kg, it can at least be concluded to be below this level. Table 4.134 shows the data for the three samples for relevant phthalates.

Table 4.134 Expanding fillers phthalate quantitative results

Sample	Description	Classified (hazard statement codes) (mg/kg)	Non-Classified (mg/kg)	
		DEHP/DIOP	DNOP	DIDP
3063	Expanding filler from a fire door	-	<40	<730
R035	Expanding filler	<1,900	<40	<700
6015	Expanding filler	<2,600	<50	1,010

UV-328

UV-328 was not identified above LOQ the of 200 mg/kg in the three expanding filler samples sent for quantitative analysis.

Organophosphates

The results of the quantitative OPFRs analysis are provided in Table 4.135.

Table 4.135 Expanding fillers organophosphate results

Sample	Description	TCPP (mg/kg)
1217	Expanding filler	113,730
3073	Expanding filler from a window frame	87,290
3083	Expanding filler	80,370
N11	Expanding filler	24,600
R035	Expanding filler	18,550

Note: Red shading hazardous property threshold exceeded

As identified in in the screening analysis TCPP was found above 10,000 mg/kg in all samples sent for quantitative analysis. As TCPP is classified as H351 all samples exceed the 10,000 mg/kg threshold for HP 7, carcinogenic. None of the samples exceed the 250,000 mg/kg threshold for HP 6 or HP 14.

Brominated flame retardants (Fraunhofer)

Due to the suspected high potential for BFRs to be present in this waste category two expanding filler samples were submitted to the Fraunhofer Institute for quantitative analysis to provide a second benchmark. This laboratory has experience in testing this waste matrix. PBDEs were detected above the LOQ in both samples analysed as outlined in Table 4.136.

Table 4.136 Fraunhofer expanding filler BFR results

Sample	XRF (mg/kg)		Classified (POPs) (mg/kg)			Classified (hazard statement codes) (mg/kg)		Non-Classified (mg/kg)		
	Bromine	Antimony	tetra- to hepta-BDE	deca-BDE	HBCD	octa-BDE	TBBPA	mono- to tri-BDE	nona-BDE	DBDPE*
2164	27,468	41,067	<7.5	164	<95	<2	<85	<1.00	6.61	<2.5
4033	35,327	37,607	<7.5	111	<95	<2	<85	<1.00	4.12	<2.5

Note: Orange shading above LOQ

Comparing the concentration of PBDE in these two samples with the POPs threshold of 500 mg/kg for the sum of POPs classified PBDEs (tetra-, penta-, hexa-, hepta- and deca-BDEs), neither sample had a concentration above the POPs threshold. However, both samples were found to have a deca-BDE concentration above 100 mg/kg. Excluding deca-BDE no other POPs classified PBDEs were detected above the LOQ.

HBCD was not detected above LOQ in either sample. As the POPs threshold for HBCD is 1,000 mg/kg, despite a potential problem with the quantification of HBCD extraction (as outlined in Section 6.4) there is reasonable confidence that neither sample exceeds this threshold.

Two other common BFR compounds were also analysed in the suite, TBBPA and DBDPE. Neither were identified above LOQ in either of the samples analysed.

To determine extraction efficiency of the brominated compounds analysed, the samples underwent XRF analysis before and after extraction as outline in the Fraunhofer analysis approach (Section 3.4.3). The results of this analysis are provided in Table 4.137.

Table 4.137 Fraunhofer expanding filler extraction efficiency

Sample	Input bromine (mg/kg)	Output bromine (mg/kg)	Extraction efficiency (%)
2164	27,468	19,870	27.7
4033	35,327	13,550	61.6

Both expanding filler samples were elected because of their significantly elevated bromine content, however, for sample 2164 just over a quarter of the bromine was extracted from the sample for analysis. Similarly sample 4033 just over half of the detected bromine was extracted. This would suggest the presence of PolyFR which is a substance that is covalently bonded into the polymer matrix and therefore is virtually impossible to extract and cannot be quantified (details are outlined in Section 6.4).

The concentration of nona- and deca-BDE were detected at a much lower concentration than the total bromine extracted from each sample (<3%). This potentially indicates the presence of an unidentified soluble BFR within the sample.

Polychlorinated Biphenyls (PCBs)

Of the 25 samples selected for PCB analysis a single expanding filler sample was selected for analysis. The results of the analysis are provided below in Table 4.138.

Table 4.138 Expanding filler PCB quantitative results

Sample	Sum of total PCB (mg/kg)	Sum of ICES6 (mg/kg)	Sum of dl-PCB (mg/kg)	dl-PCB WHO 2005 TEQ (ng/kg)	dl-PCB WHO 2005 TEQ (ng/kg)
2089	0.015	0.007	0.002	0.94	0.56

The sample tested was significantly below the POPs threshold of 50 mg/kg for total PCB content with a concentration of 0.02 mg/kg.

The ratio of ICES6 to total PCB content was 0.47. As this ratio is based on a single data point, more testing would be required to potentially provide evidence on how ICES6 analysis could be scaled to estimate total PCB concentration of this waste stream.

The dioxin like PCB (dl-PCB) concentration was also very low. The concentration measured was 0.002 mg/kg. When scaled using the WHO 2005 TEFs, the TEQ value was well below the EU POPs threshold of 5 µg/kg (5,000 ng/kg) with the upper bound value measured being 0.0009 mg/kg. (0.94 ng/kg). Using the WHO 2022 TEFs shows a reduction in the TEQ.

The analysis by MSS demonstrated high recovery rates for the spiked samples. The average recovery observed for the dl-PCBs was 89% (+/-2%), and for the ICES6 was 80% (+/-3%).

4.11.5. Summary

From quantitative analysis, SCCPs, MCCPs and OPFRs were found to be present in expanding filler at concentrations exceeding relevant thresholds.

The only sample found to exceed the POPs threshold for SCCPs was in the expanding fillers category, in a product purchased new for this study which had a concentration of 52,900 mg/kg, five times the POPs threshold of 10,000 mg/kg. Three other samples contained SCCPs, all above the potential future POPs threshold of 1,500 mg/kg.

MCCPs were quantified in eight samples, with five of these exceeding concentrations of 100,000 mg/kg. Both SCCPs and MCCPs are classified as H410 and of the nine samples submitted for quantitative analysis, seven had concentrations exceeding the 2,500 mg/kg threshold for HP 14.

In addition to the CPs, OPFRs were also present, with all six samples submitted for quantitative analysis being reported as having concentrations above 10,000 mg/kg, with two samples exceeding 100,000 mg/kg. The OPFR present was TCPP, classified as H302, H351 and H412. All samples exceeded the 10,000 mg/kg H351 threshold for HP 7.

Table 4.139 summarises the results for the quantitative analysis of expanding fillers. This summary is based on targeted analysis of samples suspected to contain relevant substances and may therefore not be representative of the waste stream as a whole. It can however provide an indication on the prevalence of the relevant classified substances in this waste stream, allowing a “high, medium, low” relative prevalence to be assigned. Commentary is provided for any substances assigned medium or high.

Table 4.139 Summary of the prevalence of classified substances in expanded fillers

Substance	Relative prevalence	Commentary
deca-BDE	Low	
tetra- to hepta-BDE	Low	
HBCD	Low	
Dechlorane plus	Low	
UV-328	Low	
SCCPs	High	SCCPs were found in four samples, with one sample exceeding the POPs threshold. This was a newly purchased sample.
MCCPs	High	MCCPs were prevalent in expanding fillers and are a known ingredient in their manufacture. Five samples had a concentration of over 10,000 mg/kg.
Classified BFRs	Low	
Classified phthalates	Low	
Classified OPFRs	High	OPFRs were found to be common in expanding fillers, with a concentration of over 10,000 mg/kg in six samples.

XRF scanning did not highlight any elements that are indicative of classified substances not included in quantitative analysis, summarised in Table 4.140.

Table 4.140 Summary of key elements in expanded fillers

Element	Relative prevalence	Commentary
Arsenic	Low	
Antimony	Low	
Lead	Low	
Zinc	Low	

Table 4.141 shows the number of samples which exceeded at least one threshold. Three samples exceeded thresholds for both CPs and TCPP. As further categories were not defined, all samples with quantitative results are presented.

Table 4.141 Expanding filler samples that exceed thresholds

Sample	Description	Samples exceeding POPs thresholds (n)	Samples exceeding hazardous property thresholds (n)	
		Quantitative	Quantitative	
		SCCPs	CPs (sum)	TCPP
1217	Expanding filler	<100	450	113,730
3063	Expanding filler from fire door	<500	195,000	-
3073	Expanding filler from window	<600	2,200	87,290
3083	Expanding filler	<700	4,700	80,370
2195	Expanding filler	<600	344,500	-
N10	Expanding filler	52,900	59,100	-
N11	Expanding filler	1,600*	202,200	24,600
R035	Expanding filler	2,800*	155,670	18,550
6015	Expanding filler	3,600*	155,670	-
Total:		1 (9)	7 (9)	5 (5)

*Above possible future UK threshold of 1,500 mg/kg.

4.12. Roofing

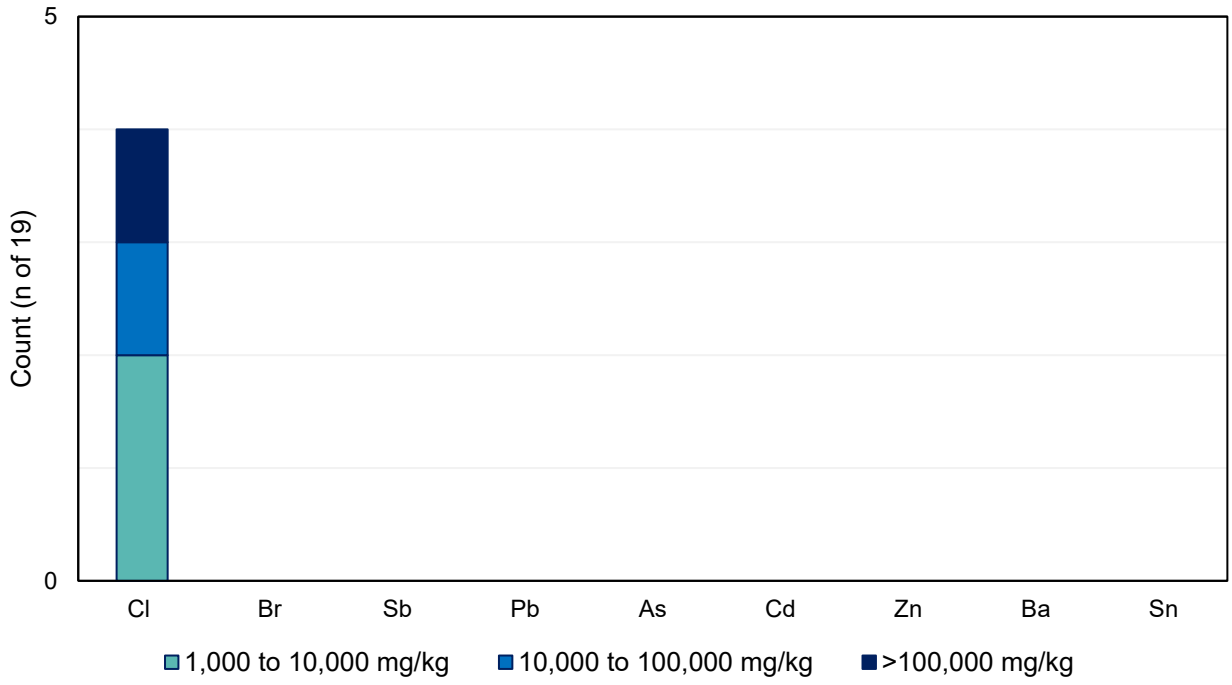
4.12.1. Sample collection

A total of 18 roofing samples were collected during sampling. Samples of this category were of interest but were relatively limited due to availability during sampling which was largely focussed on internal fittings and fixtures. Due to the wide range of individual roofing types, this category was not divided into sub-categories. Samples included materials such as ceiling barrier membrane and roofing felt.

4.12.2. XRF analysis

All samples collected underwent XRF analysis in triplicate. The range of target element concentrations recorded in the adhesive and sealant category are outlined in Figure 4.23.

Figure 4.23 Roofing XRF results



No samples were found to contain bromine above 120 mg/kg. Antimony was not identified above the threshold of detection in any sample. Of the 18 samples analysed, four were found to contain chlorine above 1,000 mg/kg, one of which had a concentration above 100,000 mg/kg.

4.12.3. Chemical Screening

Sample selection

A total of three roofing samples were selected for chemical screening, retaining the proportion of these samples in the overall sample population (2%).

Screening results – POPs

Of the six POPs compounds included in the screening list none were detected. A single BFR, BEHTBP, was detected below 1,000 mg/kg in sample 1034 (ceiling board). This compound is not classified although it has been assessed to be very persistent and very bioaccumulative (vPvB) by ECHA and may become of interest in the future.

Screening results – classified substances

Of the three samples analysed no substances with hazardous classifications were detected.

4.12.4. Quantitative analysis

Sample Selection

Sample 1056 (corrugated plastic) was sent for phthalate and UV-328 quantitative analysis due to the potential requirement for UV degradation resistance. Sample 1150 and 1056 were selected for PFAS quantitative analysis due to the potential requirement to moisture resistance.

Phthalates

The singe sample (1056) was found to contain a single non classified phthalate (DIDP) phthalate at a concentration of 1,080 mg/kg. This was not detected in the screening analysis.

UV-328

UV-328 was not quantified above the LOQ of 200 mg/kg.

PFAS

Of the two samples analysed no PFAs compounds were detected above LOQ of 5 µg/kg.

4.12.5. Summary

Although roofing is a product category of interest, it was not abundant in the waste stream and as a result only 18 samples were identified during site visits. Chemical screening and quantitative analysis did not identify any classified substances (POPs or with hazard statement codes) above the associated LOQ.

A sample, of a rubber like roofing product, was found to contain zinc, likely present as zinc oxide, at a concentration exceeding the H410 hazardous threshold of 2,500 mg/kg for HP 14.

4.13. Wood

4.13.1. Sample collection

A total 55 wood samples were collected during this project. The samples collected were divided into two sub-categories outlined in Table 4.142.

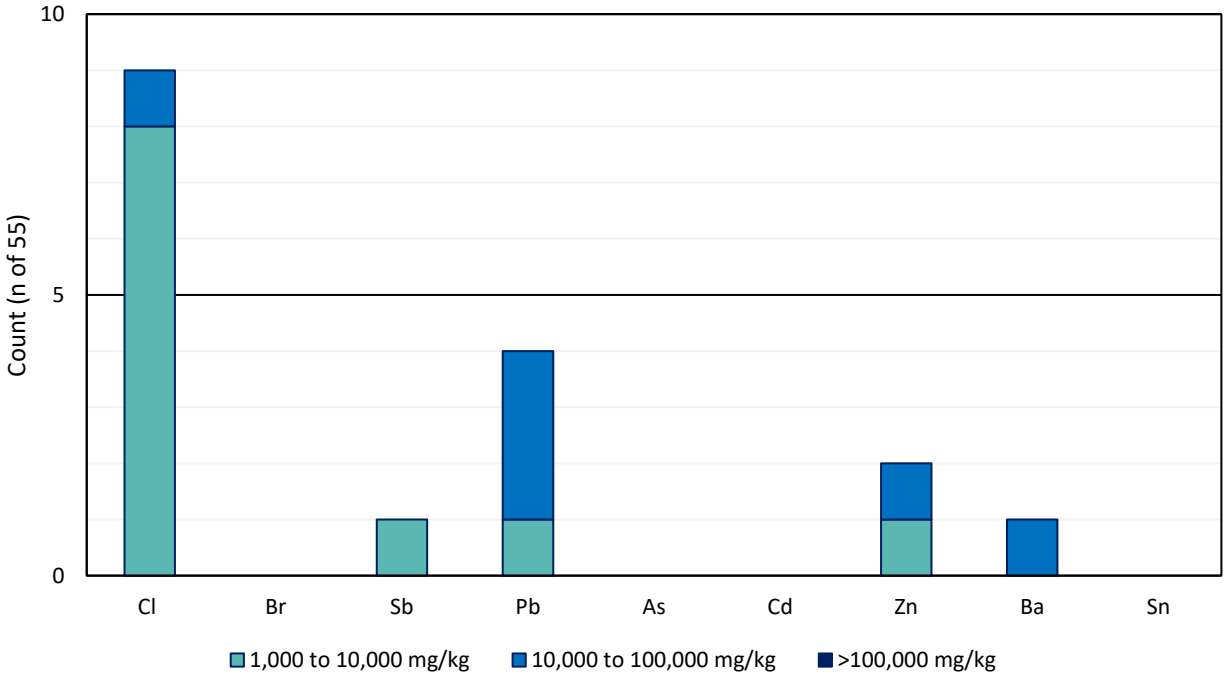
Table 4.142 Wood sub-categories

Category	Count	Description
Solid wood	10	Wood made for a single solid piece (e.g. structural timber)
Composite wood	45	Items formed from wood fibre products (e.g. MDF, chipboard etc.

4.13.2. XRF scanning

All samples collected underwent XRF scanning in triplicate. The range of target element concentrations recorded in the wood category is outlined in Figure 4.24.

Figure 4.24 Wood XRF results



No samples were found to contain bromine above 170 mg/kg. A sample (1129 – painted wood trim) with antimony concentration of 3,650 mg/kg was the only sample found to contain antimony above the LOD. The sample also had the highest barium concentration (13,655 mg/kg) and the highest lead concentration (44,821 mg/kg). An image of the sample is provided in Photograph 4.5.

Photograph 4.55 Sample 1129 – painted wood trim

Unlike the majority of samples which are made from a single material (e.g. PVC) the wood category often had paint covering one or multiple surfaces. As XRF is a surface-based analysis this elevated metal concentrations could be predominantly the composition of the paint and since the paint does not make up a significant weight of the sample this could result in an over-estimation of the metal concentrations in this type of sample.

Three additional samples were also found to contain lead above 1,000 mg/kg, all of which were visually consistent with older pieces of painted wood.

A total of nine samples were found to contain chlorine above 1,000 mg/kg with a single sample having a chlorine concentration above 10,000 mg/kg. All samples where chlorine was identified above 1,000 mg/kg were composite wood samples.

4.13.3. Chemical Screening

Sample selection

A total of three composite wood samples were selected for screening (1208 ,3099 and 3127), resulting in an under representation of this product (wood represented 5% of all samples taken but 2% of all samples sent for chemical screening). Minimal samples were selected for further screening as this category was already the subject of other on-going studies which overlapped with this study.

Screening results – POPs

Of the six POPs compounds included in the screening list none were detected. No substances proposed for listing under the Stockholm Convention (i.e. MCCPs) or ECHA classified persistent, bioaccumulative and toxic (PBT) compounds were detected.

Screening results – classified substances

Of the three samples analysed no compounds with hazardous classifications were detected.

4.13.4. Quantitative analysis

Due to the relative low prioritisation of this category combined with no compounds of interest being identified in chemical screening no wood samples were sent for quantitative analysis.

4.13.5. Summary

Wood waste is known to contain classified substances due to the chemicals used for treatment and in paints. This study did not focus on wood for chemical screening or quantitative analysis. XRF scanning highlighted lead concentrations in paints, however as XRF is a semi-quantitative surface-based screening method, using the concentrations to characterise coated samples is not appropriate. Table 4.143 shows the number of samples where hazardous property thresholds may be exceeded.

Table 4.143 Wood samples exceeding thresholds

Category	Total collected (n)	Samples exceeding hazardous property thresholds (n)	
		XRF	
		Lead*	Zinc*
Wood	55	3	1
Solid wood	10	1	1
Composite wood	45	2	0

*Potential overestimation in total concentration due to paint.

4.14. Other

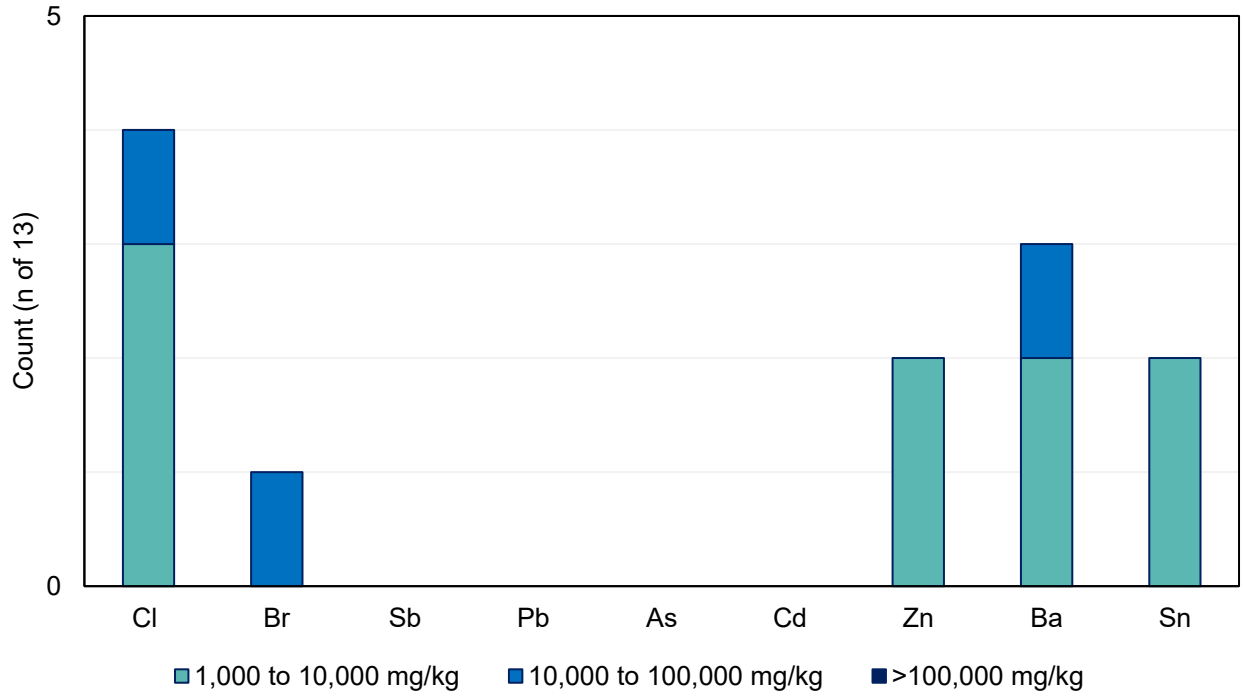
4.14.1. Sample collection

A total of 13 samples were selected during this project which did not fit into any of the previous categories. This included both mineral samples (such as brick and asphalt), metals and WEEE.

4.14.2. XRF analysis

All samples collected underwent XRF analysis in triplicate. The range of target element concentrations recorded in the wood category are outlined in Figure 4.25.

Figure 4.25 Other XRF results



A single sample (3049) was identified to have a bromine concentration above 1,000 mg/kg (18,500 mg/kg). As this sample was a printed circuit board it should be classified as WEEE which was not a target waste steam in this investigation.

A single sample (R039 a circuit board and switch) was identified to contain antimony above the LOD however, this concentration was well below 1,000 mg/kg (150 mg/kg).

Of the samples analysed four were found to contain chlorine above 1,000 mg/kg (two brick samples and two metal samples).

4.14.3. Chemical Screening

As the samples were placed into this category because they were out with the scope of the project, none were selected for further chemical screening or quantitative analysis.

5. Discussion

5.1. POPs assessment

The UK is party to the Stockholm Convention which is implemented by domestic regulations. At time of writing (February 2025) a total of nine POPs classified compounds and seven compounds proposed for listing under the Stockholm Convention were included in the various quantitative analysis suites. A list of these compounds is outlined in Table 5.1 along with an indication as to whether they were detected in the sampled C&D waste stream (denoted by a tick and highlighted in green).

Table 5.1 POPs list

Group	Compound	Detected
POPs classified		
Brominated flame retardants	PBDEs	✓
	HBCD	✓
Chlorinated paraffins	SCCPs	✓
PFAS	PFOS	
	PFHxS	
	PFOA	
Other	UV-328	
	DCP	
Substances proposed for listing under the Stockholm Convention		
Chlorinated paraffins	MCCPs	✓
PFAS	PFNA	
	PFDA	
	PFUnDA	
	PFDoDA	
	PFTrDA	
	PFTeDA	

A summary of the analytical results gathered during this project are provided in this section by chemical group (Section 4 provides all available screening and testing data by waste category).

5.1.1. Brominated flame retardants

Polychlorinated Biphenyls (PDBEs)

POPs classified PBDEs include five congeners which are outlined in Table 5.2.

Table 5.2 PBDE POPs congeners

Isomer	CAS No.
tetra-BDE	5436-43-1
penta-BDE	32534-81-9
hexa-BDE	36483-60-0
hepta-BDE	273-031-2
deca-BDE	1163-19-5

The POPs threshold for the concentration of the five PBDEs is soon to be reduced to 500 mg/kg and following advice from the EA this threshold has been used for the POPs evaluation in this report.

A summary of the samples where PBDE POPs classified compounds were detected in the VU analysis is provided in Table 5.3. Due to the semi-quantitative nature of the screening analysis PBDEs could not be divided into individual congeners and the data is therefore divided into two groups, deca-BDE and PBDEs excluding deca-BDE. As there are several PBDE isomers that are not POPs classified (e.g. octa- and nona-BDE) this could theoretically result in an over estimation of the POPs exceedance however this was not found to be the case. For the quantitative analysis the individual POPs classified congeners were determined however these have been grouped as tetra- to hepta-BDE to aid presentation of the data.

Of the seven samples where POPs classified PBDEs were detected through quantitative analysis, five were identified at the screening stage. For sample N6 the quantitative deca-BDE concentration was low which is potentially why it was not identified by screening. As this concertation is below the POPs threshold of 500 mg/kg this does not impact classification of this sample.

Sample 4027 however, had a POPs PBDE sum of over 30,000 mg/kg. This sample was not identified to contain any PBDEs at any concentration in the screening analysis and illustrates a potential shortfall in the screening approach. Without quantitative testing, use of the screening data would have resulted an incorrect POPs classification. Table 5.4shows the breakdown of PBDEs within this sample.

There is a significant correlation between elevated PBDEs and elevated XRF bromine and antimony concentrations.

Table 5.3 VU PBDE POPs summary

Sample	Category	Description	XRF (mg/kg)		Screening (mg/kg)		Quantitative (mg/kg)	
			Bromine	Antimony	PBDE (*excluding Deca-BDE*)	deca-BDE	tetra- to hepta-BDE	deca-BDE
4027	Fixtures and fittings	Cable Velcro ties	52,485	<18	ND	ND	31,220	<150
4049	Pipes	Cable ducting	12,922	6,342	ND	1,000 to 10,000	<530	3,950
4067*	Insulation	Foam rubber	51,295	3,530	ND	>10,000	<440	53,600
4080	Pipes	Cable duct end	1,918	1,314	ND	<1,000	<480	1,200
4102	Plastics	Tray	17,734	5,622	ND	1,000 to 10,000	<530	11,500
4143	Plastics	Cabinet divider	6,382	1,929	ND	1,000 to 10,000	N/A	N/A
5037*	Insulation	Ceiling tile	9,687	638	ND	<1,000	<480	920
N6*	Insulation	XPS insulation	663	<18	ND	ND	<550	260

Table 5.4 PBDE breakdown of sample 4027

Sample	tetra-BDE	penta-BDE	hexa-BDE	hepta-BDE	deca-BDE
4027 (mg/kg)	12,800	16,900	1,490	30	<150

An additional 20 samples (18 insulation and two expanding fillers) were also sent to Fraunhofer for BFR analysis. This included quantification of PBDEs. As outlined in the method section (Section 3.3.4) Fraunhofer analysed individual PBDE congeners which were then grouped into isomer bands (mono- to deca-BDE). For the POPs classified PBDEs tetra- to hepta-BDE were not detected in any sample analysis. Deca-BDE was however found above LOQ in 16 samples as outline in Table 5.5.

Table 5.5 Fraunhofer PBDE POPs summary of samples above LOQ

Sample	Category	Sub-Category	XRF (mg/kg)		Quantitative (mg/kg)
			Bromine	Antimony	Deca-BDE
1122*	Insulation	Other insulation	12,877	2,970	5.53
2164	Expanding filler	-	27,468	18	163.6
2174	Insulation	Foam rubber	39,237	1,616	30.82
4028	Insulation	Foam rubber	53,893	3,677	128,480
4033	Expanding filler	-	35,327	18	110.6
4067*	Insulation	Foam rubber	51,295	3,530	160,273
4074*	Insulation	Foam rubber	8,424	10,717	22.82
4105	Insulation	Foam rubber	72,844	13,948	51,992
4107	Insulation	Foam rubber	40,063	1,559	62,010
4118	Insulation	Foam rubber	7,960	1,191	166.4
5019	Insulation	Foam rubber	111,701	39,618	100,808
5037*	Insulation	Other insulation	9,687	638	4,012
N5	Insulation	EPS insulation	789	18	59.39
N6*	Insulation	XPS insulation	663	18	295.9
N8*	Insulation	XPS insulation	3,441	18	86.57
N17	Insulation	XPS insulation	486	18	860.5

* Analysed by VU and Fraunhofer

Of the seven insulation samples found to contain deca-BDE above the POPs threshold five were categorised as foam rubber. All rubberised insulation samples sent for quantitative PDBE analysis at Fraunhofer were found to contain PBDEs at concentrations above the LOQ. This is a significant trend that may warrant further investigation.

Sample N17 was a newly purchased piece of XPS insultation that was found to contain deca-PBDE above the POPs threshold. All XPS samples sent for analysis at FH were found to contain deca-BDE above LOQ. As these samples were all newly manufactured there is a potential that POPs classified XPS insulation is still entering the construction industry and is not solely present in legacy materials. If this is the case this could negatively impact the composition of the waste stream for decades to come.

It must be noted that of the samples analysed by both VU Amsterdam and Fraunhofer institute, significantly different results were reported for two samples (4067 and 5037). This is discussed in further detail in Section 4.1. Sample 4067 would exceed the POPs threshold based on VU data but was below the threshold based on Fraunhofer data. The exceedance value has been used in the summary.

A summary of the POPs exceedance rate based on the quantitative analysis by each category is provided in Table 5.6. It should be noted that screening and quantitative analysis was carried out on targeted samples likely to contain the substance of interest and so may not be representative of the overall waste stream. An investigation on a specific category or waste material would be required to conclusively determine a POPs classification.

Table 5.6 BDE POPs exceedance by category (VU and Fraunhofer results)

Category	XRF (n)		Screening (n)		Quantitative BFR (n)	
	Count	Bromine > 1,000 mg/kg	Count	Screening PDBEs (any) detected	Count	PDBE (sum) above POPs threshold
Total (all categories)	1032	77 (7.5%)	131	6	60	11
Insulation	188	20 (10.6%)	35	2	24	7
Plastic products	150	7 (4.6%)	22	2	5	1
Pipes	118	4 (3.4%)	21	2	3	2
Flooring	85	1 (1.2%)	11	0	0	0
Fixtures and fittings	57	17 (30%)	21	0	16	1
Discarded construction materials	45	8 (18%)	11	0	4	0
Expanding fillers	31	7 (23%)	10	0	8	0

Insulation waste represented the largest number of samples found to contain PBDEs (all deca-BDE) over the POPs threshold, however it was also the category with the greatest number of samples sent for quantitative analysis. PBDEs were also present in plastic products, pipes and fixtures and fittings, with the latter exceeding the threshold due to tetra-BDE and hepta-BDE rather than deca-BDE.

Fixtures and fitting were selected to make up a significant proportion of the samples sent for quantitative testing despite the screening results due to the high percentage of elevated bromine results in the XRF scanning and the assumed likelihood of BFR presenting in the waste stream due to their commonly proximity to electrics. Despite this, only one sample was identified to contain POPs classified PBDEs above the LOQ. The

source of the elevated bromine concentration determined in the XRF scanning was not determined for the other 15 samples.

Hexabromocyclododecane (HBCD)

HBCD was included as a compound in the screening and quantitative BFR analysis by VU Amsterdam. However, it was not detected in any of the 200 samples sent for screening above the LOQ or the 51 samples tested using quantitative techniques.

HBCD was included in the BFR suite for the 20 samples selected for quantitative analysis by Fraunhofer but was only detected in one sample. The sample where HBCD was identified was 1051, EPS insulation. The HBCD result for this sample however could only be provided as a minimum value due to problems which quantification (as outlined in Section 6.4.2). As the concentration value of >764 mg/kg could potentially be above the 1,000 mg/kg threshold, a definitive classification cannot be determined. It is therefore clear that further development of the analytical approach is required to provide a robust HBCD concentration.

The sample with HBCD detected (1051) by Fraunhofer was reported as below the LOQ of 150 mg/kg by VU Amsterdam. This could potentially be due to the difficulties in quantifying substances in porous materials such as insulation, which is discussed further in Section 6.4.

5.1.2. Chlorinated paraffins

SCCPs

SCCPs currently have a POPs threshold of 10,000 mg/kg however, there is potential for this to be reduced to1,500 mg/kg in the future. The EU has already implemented a 1,500 mg/kg threshold for SCCPs in waste, and this was the lead opinion presented in the March 2023 consultation on potential amendments to the Persistent Organic Pollutants (POPs) Regulation.

SCCPs were detected in a total of 10 out of the 200 samples sent for screening. All 10 samples were sent for quantitative SCCPs analysis, along with 52 other samples with a range of chlorine concentrations. The results of this analysis are provided in Table 5.7.

From this analysis several points of interest can be drawn. Firstly, for the ten samples identified to contain SCCPs in the screening, all were found to have a SCCPs concentration within their assigned concentration band in quantitative testing. A slight caveat to this was that samples 1069 and 1210, which were discarded construction material, were found to have an LOQ above 5,000 mg/kg, which was therefore within the predicted concentration band. This is due to the samples requiring further dilution for analysis due to the presence of high concentration interfering substances as outlined in Section 6.4. This outcome may need to be addressed in future analysis of the POPs threshold is reduced to 1,500 mg/kg. Sample N10 was the only sample found to exceed the current POPs threshold for SCCPs which was supported by the screening data.

Table 5.7 SCCPs POPs summary

Sample	Category	Description	XRF	Screening	Quantitative
			Chlorine (mg/kg)	SCCPs (mg/kg)	SCCPs (mg/kg)
1069	Discarded construction materials	Recycled plastic cone	92,382	1,000 to 10,000	<5,200
1210	Discarded construction materials	Recycled plastic barrier stand	157,108	1,000 to 10,000	<5,300
2107	Doors and window frames	Window frame	51,988	ND	1,600
4002	Cladding and wall panels	Wallpaper with plastic mesh	98,457	1,000 to 10,000	2,600
4067	Insulation	Foam rubber	264,850	1,000 to 10,000	2,200
4152	Plastics	Fire signage	459,256	1,000 to 10,000	5,100
5012	Doors and window frames	Door trim	2,424	1,000 to 10,000	5,200
5015	Flooring	Vinyl flooring	155,869	ND	2,900
N10	Expanding filler	Expanding filler	107,546	>10,000	52,900
N11	Expanding filler	Heavy duty expanding foam	80,650	1,000 to 10,000	1,600
N12	Adhesives and sealants	Elastic sealant	15,279	ND	1,600
R035	Expanding filler	Expanding filler	30,954	1,000 to 10,000	2,800
6015	Expanding filler	Expanding filler	32,767	1,000 to 10,000	3,600

Three samples did not contain SCCPs in the screening were found to have SCCPs concentrations above 1,000 mg/kg in the quantitative analysis. The window frame and elastic sealant samples which had two of the lowest concentrations recorded in screening contained 1,600 mg/kg in the quantitative analysis. Sample 5015 (vinyl flooring) however had a quantitative concentration above several of the other samples where SCCPs were detected in the screening. All three samples would exceed a potential future POPs threshold of 1,500 mg/kg.

Sample N10, which exceeded the current POPs threshold for SCCPs, is a newly purchased material which would suggest that POPs classified materials are still being used in current construction products.

A reduction of the SCCPs POPs threshold to a threshold of 1,500 mg/kg would increase the overall number of exceedances from one to 13.

MCCPs

MCCPs are currently proposed for listing under the Stockholm convention by the UK. MCCPs in the analysis were classified as chloro-alkanes with chain length of C14 to C17 (CAS number 85535-85-9).

A total of 31 samples had an MCCPs contribution above 1,000 mg/kg in the quantitative analysis. This included all 19 samples identified above 1,000 mg/kg from chemical screening, which means that 12 samples were not correctly identified by screening. These samples were from a range of categories and were found to have a range of concentrations between 1,500 and 18,300 mg/kg. This highlights major uncertainty in the effectiveness of determining MCCPs levels by chemical screening.

If MCCPs were to be listed under the Stockholm convention as POPs, a low POP concentration limit would likely be implemented. As this value has not yet been determined the number of samples potentially exceeding a threshold cannot be determined. Quantitative analysis can be used to identify 20 samples with a concentration of MCCPs over 10,000 mg/kg (the current SCCPs threshold) and 31 samples were found to have a concentration over 1,500 mg/kg. The listing of MCCPs under the Stockholm convention is therefore likely to significantly increase the number of items in the C&D waste stream which exceed POPs thresholds.

A summary of the POPs exceedance rate based on the quantitative analysis by category is provided in Table 5.8. It should be noted that screening and quantitative analysis was carried out on targeted samples likely to contain the substance of interest and may therefore not be representative of the waste stream as a whole. An investigation on a specific category or waste material would be required to conclusively determine how the listing of MCCPs would affect the number of exceedances.

Table 5.8 MCCPs theoretical POPs exceedance by category

Category	XRF		Screening (n)			Quantitative (n)		
	Count	Chlorine > 10,000 mg/kg	Count	MCCPs 1,000 -10,000 mg/kg	MCCPs >10,000 mg/kg	Count	MCCPs >1,000 mg/kg	MCCPs >10,000 mg/kg
Total (all categories)	1032		151	19	16	52	30	20
Insulation	188	43 (23%)	35	4	4	12	6	4
Plastics	150	45 (30%)	22	1	0		2	
Pipes	118	46 (39%)	21	0	0	1	1	1
Flooring	85	34 (40%)	11	1	1	4	2	1
Doors and window frames	78	68 (87%)	22	1	1	5	2	1
Adhesives and sealants	66	6 (9.1%)	15	2	2	9	4	3
Cladding and wall panels	66	34 (52%)	18	1	1	4	2	2
Rubber products	62	8 (13%)	8	0	0	6	2	1
Discarded construction materials	45	3 (6.7%)	11	2	2	2	2	2
Expanding fillers	31	19 (61%)	10	7	5	9	8	5

The category with the greatest number of samples exceeding 10,000 mg/kg MCCPs was expanding fillers. This product is known to be manufactured using CPs, and although this category was not abundant in the waste stream (only 31 samples were obtained in total across the field study) they could present a particular concern in the future if MCCPs were to be listed under the Stockholm Convention.

Aside from expanding fillers, MCCPs were also present in insulation, in particular rubber-based insulation, as outlined in the insulation Section 4.1.

5.1.3. PFAS

PFAS compounds were not included in the initial screening analysis as predicted concentrations were likely to be below those that could be identified by the screening test. Concentrations found at the lowest concentration (<1,000 mg/kg) band would not provide useful information on the potential POPs threshold exceedance of the samples. Therefore, only quantitative results are available for the 20 samples selected for this analytical suite based on the waste category and likely use.

No compounds included in the PFAS analysis suite (including PFOS, PFOA and PFHxS) were identified above the LOQ value of 5 µg/kg in any of the 20 samples selected for quantitative analysis.

PFOS

PFOS has a current POPs threshold of 50 mg/kg. As this threshold is 10,000 times greater than the LOQ of the analysis, there is confidence that none of the samples analysed exceeded this threshold.

PFOA and PFHxS

Although PFOA and PFHxS are listed under the Stockholm convention there are currently no POPs thresholds assigned by the regulator. PFOA and PFHxS were included in the Defra industry consultation on potential amendments to the POPs Regulation. The general lead threshold option identified for both PFOA and PFHxS is 1 mg/kg. As this threshold is 200 times larger than the LOQ value for the PFAS suite, there should be reasonable confidence that the samples collected and analysed in this project would not exceed future POPs thresholds for these substances.

5.1.4. UV-328 and Dechlorane plus

UV-328 and Dechlorane Plus (DCP) although listed under the Stockholm convention currently have no low POP concentration limits, and as a result no threshold to compare the concentration to within this study.

Dechlorane plus was not quantified in any sample above the LOQ of between 60 and 80 mg/kg. This is a strong indication that it has not been used as an additive in construction products currently being disposed to the national waste stream.

UV-328 was also not quantified in any sample above the LOQ of 200 mg/kg. This is evidence that this substance is unlikely to be present in products as an additive where concentrations of over 1,000 mg/kg would be expected. However, if being used as a coating, the LOQ of 200 mg/kg may not be sufficient to quantify the relative low concentrations that may be present and depending on the low POP concentration limit that is introduced, more accurate analysis methodologies may be required.

5.1.5. Polychlorinated biphenyls (PCBs)

Quantitative testing for dioxin like PCBs (dl-PCBs) and total PCBs was carried out on 20 samples. PCBs were not included in screening and all 20 samples targeted were mainly adhesives and sealants. No sample contained PCBs above the current POPs threshold of 50 mg/kg. When scaled using the world health organisation (WHO) 2005 toxic equivalent factors (TEFs), the toxic equivalent (TEQ) value for all samples was well below the EU POPs threshold of 5 µg/kg (5,000 ng/kg) with the highest upper bound value measured being 0.024 µg/kg. (23.6 ng/kg). The UK does not have a specific POPs limit for dl-PCBs.

5.1.6. Summary

Across all POPs substances and all categories (a total of 1032 samples), 11 samples were found to contain PBDEs over the 500 mg/kg threshold, and one sample was found to contain SCCPs over the current 10,000 mg/kg threshold. HBCD was detected in one sample at a quantity of over 700 mg/kg, but due to difficulties in quantification it cannot be concluded if this is over the current 1,000 mg/kg POPs threshold.

For the remaining substances listed as POPs, PFASs, PCBs, [UV-328 TBC] and dechlorane plus were not detected in any sample above the associated limit of quantification (LOQ). There is currently no associated POPs threshold to classify any item as POPs waste by PFOA, PFHxS, UV-328 or dechlorane plus, and so a POPs classification will depend on these being established.

MCCPs are proposed for listing under the Stockholm Convention as a POP, if this comes into effect it will have a dramatic impact on the number of exceedances, as 20 samples were found to contain MCCPs in concentrations above 10,000 mg/kg.

5.2. Substances classified with hazard statement codes

Alongside POPs, this study also aimed to identify and quantify a number of substances classified with hazard statement codes which may be present in construction products, and which could therefore impact the classification of construction and demolition waste. These substances are detailed in Section 2.2 of this report. Table 5.9 summarises the classified substances included in quantitative analysis and associated hazardous properties for which substances have relevant hazard statement codes.

Table 5.9 Classified substances included in study

Substance	HP 6	HP 7	HP 10	HP 14
Chlorinated paraffins (CPs)		✓		✓
Brominated flame retardants (BFRs)		✓	✓	✓
Organophosphate flame retardants (OPFRs)	✓	✓		✓
Phthalates			✓	

In addition to the quantified substances listed above, XRF scanning can be used to infer the potential presence of classified substances based on the concentration of key elements. XRF scanning cannot identify the compound an element is present in, and therefore worst-case compounds are used in the assessment. Since XRF is semi-quantitative, the concentration of the element is taken to be the concentration of the worst-case compound. There are four elements and corresponding compounds of relevance to this study which are outlined in Table 5.10.

Table 5.10 Worst case metal compounds for C&D HPA

Substance	Worst case compound	Hazard statement codes	HP 6	HP 7	HP 10	HP 14
Arsenic	Arsenic trioxide	H300, H350, H410	✓	✓		✓
Antimony	Antimony trioxide	H351		✓	✓	✓
Zinc	Zinc oxide	H410		✓	✓	✓
Lead	Lead compounds	H360, H410			✓	✓

A summary of the number of samples found to exceed HP thresholds is provided in Table 5.11. A sample was only counted a single time if at least one compound with a hazardous classification was found in that sample above the relevant hazardous threshold (with the number of samples sent for quantitative analysis given in brackets). This means that some samples may contain more than one classified substance in the substance group.

Table 5.11 Number of samples identified as containing classified substances above relevant thresholds

Category	Collected (n)	Number of samples with concentrations of classified substances above hazardous property thresholds based on quantitative analysis (n)				Number of samples with concentrations of worst-case compounds above hazardous property thresholds based on XRF scanning (n)			
		BFRs	CPs	Phthalate	OPFRs	Arsenic trioxide	Antimony trioxide	Zinc oxide	Lead compounds
Total	1032	7 (60)	27 (62)	11 (67)	15 (20)	15	19	42	122
Insulation	188	0 (24)	6 (12)	-	2 (5)	0	3	10	1
Plastics	150	3 (5)	1 (4)	0 (3)	0 (1)	5	3	2	19
Pipes	118	1 (3)	1 (2)	1 (6)	-	2	1	0	24
Flooring	85	-	2 (4)	3 (9)	-	0	0	7	0
Doors and window frames	78	-	1 (6)	2 (22)	-	6	2	1	52
Adhesives and sealants	66	-	4 (9)	3 (9)	-	1	0	0	2
Cladding and wall panels	66	-	2 (4)	1 (5)	1 (1)	1	2	4	13
Rubber products	62	-	1 (6)	1 (6)	-	0	2	15	1
Fixtures and fittings	57	2 (16)	0 (4)	0 (1)	7 (8)	0	6	1	3
Discarded construction materials	45	1 (4)	2 (2)	0 (2)	-	0	0	0	3
Expanding fillers	31	0 (8)	7 (9)	0 (3)	5 (5)	0	0	0	0
Roofing	18	-	-	0 (1)	-	0	0	0	0
Wood	55	-	-	-	-	-	-	1	4
Other	13	-	-	-	-	-	-	1	0

5.2.1. Brominated flame retardants (BFRs)

In addition to some BFRs having a POPs classification, some are also classified with hazard statement codes. Seven samples were found to contain these substances at concentrations over the relevant HP thresholds. Six of these exceedances were due to TBBPA, which is classified as H350 and H410, meaning the samples exceed both the HP 7, carcinogenic, and HP 14, ecotoxic, thresholds. The seventh sample contained penta-BDE above the HP 10 threshold as this substance is classified as H360. Classified BFRs were most common in the plastics and fixtures and fittings categories.

Of the BFRs without a hazard classification, the most common were deca-BDE and TBBPA-BDBPE, with the latter present in five samples in concentrations over 10,000 mg/kg.

The level of quantified BFRs matches relatively well with the screening results, however it does not account for the levels of bromine and antimony observed by XRF scanning. From the XRF elemental data, it would be expected to quantify far greater levels of BFRs in construction and demolition waste.

This apparent shortfall in quantified BFR data could be due to several reasons highlighted below. These are discussed further in Section 6.4:

- The quantitative analysis methodology is not optimised for the extraction and analysis of BFRs in C&D waste, with specific difficulties in analysing porous foams.
- Non-soluble or limited solubility BFRs are present, such as PolyFR and DBDPE.
- BFRs not included in the analytical suite are present and have been extracted, but not identified and quantified. This may be true of substances such as TBBPA derivatives which are now being manufactured and used in large quantities in Asia.

5.2.2. Chlorinated paraffins (CPs)

Both chlorinated paraffins quantified in this study, SCCPs and MCCPs, are classified with hazard statement codes. SCCPs are classified as H351 which has a HP 7 threshold of 10,000 mg/kg, and both are classified as H400 and H410 which have an additive HP 14 threshold of 2,500 mg/kg. Of the 62 samples sent for quantitative analysis, 27 contained one or both of these substances above the relevant HP threshold. The concentration of MCCPs was far greater than that of SCCPs.

MCCPs were present primarily in foam rubber insulation, adhesives and sealants and expanding fillers, both in legacy waste and samples purchased new for the project. The implication of this is the potential HP 14, ecotoxic, classification of these items of waste, and the potential POPs classification in the future.

5.2.3. Phthalates

Despite their widespread use, only 11 samples were found to contain classified phthalates above HP thresholds. Of these DEHP/DIOP, which are both classified as H360 but cannot be distinguished from one another, were the most common classified phthalates, found in seven of the 11 samples exceeding the threshold. The other phthalates with hazard statement codes present were DIBP and BBP, with BBP classified as H360 and H410 leading to both a HP 10 and HP 14 exceedance.

There were a significant number of samples, 32 of the 67 sent for quantitative analysis, which were found to contain DIDP, a phthalate with no hazard statement codes, at levels over 1,000 mg/kg. Other phthalates without a classification which were present include DINP, DNOP and DINCH. In some instances, a sample was found to contain both classified and unclassified phthalates and it was not uncommon to quantify more than one phthalate in a sample.

Phthalates with hazard statement codes were most prevalent in adhesives and sealants and flooring categories.

5.2.4. Organophosphate flame retardants (OPFRs)

Quantitative analysis of 20 samples found that 16 contained classified OPFRs in concentrations over the associated HP threshold. All exceedances were as a result of TCPP, TPP and TCP concentrations. If present, these substances were typically at concentrations of 10,000 mg/kg or more.

TPP and TCP are classified as H410, meaning eight samples exceed the HP 14, ecotoxic, classification. TCPP has a H351 classification and therefore has a 10,000 mg/kg threshold for HP 7, carcinogenic, which an additional eight samples exceeded.

The exceedances were concentrated in three categories of insulation: fixtures and fittings, and expanding fillers, with the latter two representing the majority of exceedances.

Fixtures and fittings are typically rigid plastic items expected to contain flame retardants. The finding of this project is that OPFRs are likely to be a far greater contributor to a potential HP threshold exceedance than BFRs.

Screening for OPFRs appeared to be effective, with quantitative concentrations matching well with the assigned screening bands. However, as the H410 threshold for HP 14 is within the 1,000 to 10,000 screening band, it cannot be used to conclusively characterise a sample, although as already stated, where OPFRs are present, they are typically present at concentrations above this level.

5.2.5. Arsenic, antimony, zinc and lead compounds

XRF scanning was carried out on all collected samples, and as such there is a large semi-quantitative database on the composition of C&D waste. The XRF is limited in that it does

not identify specific compounds, and therefore an assumption must be made on the form that an element is present.

The data set shows that lead was detected over 2,500 mg/kg (the relevant HP 14 threshold) in 122 samples, which was approximately 12% of all samples collected. Lead was a common additive as a stabiliser in PVC formulations, however its use in virgin compounds was voluntarily phased out by EU manufacturers by 2015[12] (although products containing recycled PVC and products manufactured outside of the EU after 2015 may still contain lead). Despite this, lead is common in doors and window frames, with 67% of samples collected in this study containing lead above the H410 threshold of 2,500 mg/kg for HP 14 and the 3,000 mg/kg H360 threshold for HP 6. Pipes and ducting, and cladding and wall panels were two other categories where 20% of samples in exceeded this threshold.

Arsenic was detected at concentrations above 1,000 mg/kg in 15 samples (six were windows and doors and five were in the plastics category). If using the worst-case compound of arsenic trioxide (since the exact compound is not known) this would exceed the H300 and H350 threshold of 1,000 mg/kg for HP 6 and HP 7 respectively. The origin of the samples in the "plastics" category was uncertain, and so it is difficult to draw any conclusions. Further speciation of arsenic would be beneficial to accurately assess the hazardous properties of the samples.

Of the four compounds, antimony trioxide has the highest HP threshold of 10,000 mg/kg for HP 7 since it is classified as H351. However, due to its presence in a number of materials, 19 samples were found to contain antimony above this level. Antimony is often present alongside bromine or chlorine and is most prevalent in the fixtures and fittings category, despite this only two samples from this category were found to contain classified BFRs over the associated HP threshold.

Zinc, likely present as zinc oxide, which is classified as H410 and therefore has a threshold of 2,500 mg/kg for HP 14 was detected at levels above this threshold in 42 samples. Zinc was present above 2,500 mg/kg in 5% of insulation (the majority being foam rubber) and 8% of flooring samples. However, the category where it was primarily present was in rubber products, where the HP 14 threshold was exceeded in 23% of samples. Zinc oxide is widely used in rubber products as an activator for vulcanisation, and therefore it is reasonable to assume this is the compound that is present.

5.2.6. Summary

As with all the data evaluation undertaken in this project, the number of samples sent for quantitative analysis and the targeted approach to sampling is a limitation when trying to extrapolate the findings for C&D waste as a whole. However, from the data that is available it is apparent that MCCPs, OPFRs, zinc oxide and lead compounds are likely to

[12] https://www.bpf.co.uk/article/vinylplus-european-commission-regulation-restricting-lead-in-p-3320.aspx

be of the greatest interest when it comes to the classified substances being present at concentrations which exceed HP thresholds. Of all categories, windows and doors and expanding fillers appear to be the most likely to contain such substances. Table 5.12 summarises the classified substances present by category.

Table 5.12 Summary of classified substances by product category

Category	Classified substances	Associated hazardous properties
Insulation	MCCPs Zinc oxide OPFRs	HP 14
Pipes	Lead compounds	HP 10, HP 14
Flooring	Zinc oxide	HP 14
Doors and window frames	Lead compounds Arsenic trioxide (worst-case)	HP 6, HP 7, HP 10, HP 14
Adhesives and sealants	MCCPs Phthalates	HP 10, HP 14
Cladding and wall panels	Lead compounds	HP 10, HP 14
Rubber products	Zinc oxide	HP 14
Fixtures and fittings	OPFRs Antimony trioxide	HP 7, HP 10, HP 14
Expanding fillers	MCCPs OPFRs	HP 7, HP 14*
Other plastics	BFRs OPFRs Lead compounds	HP 7, HP 10, HP 14

5.3. Laboratory comparison

The majority of the quantitative analysis was carried out by VU, with the Fraunhofer Institute (Fraunhofer, abbreviated to FH in tables below) carrying out quantitative analysis of 20 samples, which were mostly insulation. Both laboratories analysed nine of the same insulation samples. Table 5.13 shows the concentrations reported by the two laboratories.

Firstly, octa-BDE and nona-BDE, which are not classified as POPs PBDEs, were not included in the VU analytical suite. Secondly, VU only report below the LOQ rather than “not detected” (ND). The resolution of the Fraunhofer results is several orders of magnitude greater than VU, as Fraunhofer specialise in BFR analysis in complex matrices

and are highly experienced in this area. VU were used for most of the quantitative analysis as they were able to offer broader suites and chemical screening.

HBCD, known to be a challenging substance to quantify in insulation foam (detailed in Section 6.4.2) was detected and semi-quantified in one sample by Fraunhofer, however this was reported as below the LOQ of 150 mg/kg by VU. VU did not quantify HBCD above the LOQ in any sample, however since this one was potentially incorrectly quantified, it therefore cannot be concluded that HBDC was not present in the other samples.

The relative insolubility of DBDPE (detailed in Section 6.4.3) makes quantitative analysis virtually impossible according to Fraunhofer. In one sample Fraunhofer quantified a concentration of over 2,000 mg/kg which was reported by VU as below the LOQ of 720 mg/kg. However, in another sample, VU reported a concentration of over 2,000 mg/kg and Fraunhofer reported no detection. This potentially could be due to a labelling and reporting error or brings into question the existing methods to identify and quantify this BFR. Currently DBDPE has no classification, and so this may be of limited concern now, however, since it is structurally very similar to deca-BDE, it is possible its classification will change in the future.

There was also a difference in reporting for two samples with regards to deca-BDE. In both instances, Fraunhofer quantified significantly higher concentrations than VU. These samples had chemical screening concentrations that matched with the VU quantified concentrations. Since chemical screening and quantification were both carried out on the same extract, the difference between the two laboratories may be occurring at the extraction stage. This could be due to sample heterogeneity, or difficulty in extracting and quantifying all the deca-BDE in these samples which are known to be challenging matrices. The POPs assessment however is the same as both laboratories reported concentrations of over 500 mg/kg in both samples.

This limited laboratory comparison highlights potential inconsistencies in quantitative analysis. Further comparison on other materials where POPs classified BFRs are likely to be present would be beneficial to understand if this is unique to the challenging insulation matrix or is a more common occurrence.

Table 5.13 Comparison between quantitative BFR concentrations reported by VU Amsterdam and Fraunhofer (mg/kg)

Sample	Category	XRF	tetra- to hepta-BDE		octa-BDE		nona-BDE		deca-BDE		TBBPA		DBDPE		HBCD	
		Br	VU	FH	VU	FH	VU	FH	VU	FH	VU	FH	VU	FH	VU	FH
1051	EPS insulation	5,899	<500	ND	-	ND	-	ND	<150	ND	<310	ND	<720	ND	<150	>764
1114	PIR insulation board	2,589	<500	ND	-	ND	-	ND	<150	ND	<310	ND	<720	6	<140	ND
1122	Other insulation	12,877	<500	ND	-	ND	-	ND	<150	6	<310	ND	<720	2122	<140	ND
4067	Foam rubber	51,295	<440	ND	-	66	-	3940	53,600	160,273	<270	ND	<620	ND	<140	ND
4074	Foam rubber	8,424	<570	ND	-	ND	-	<2.5	<180	22.8	<350	ND	2020	ND	<190	ND
5037	Other insulation	9,687	<480	ND	-	<1	-	84.7	920	4,012	<290	ND	<680	ND	<160	ND
2131	XPS insulation	1,411	<550	ND	-	ND	-	ND	<170	ND	<340	ND	<790	ND	<180	ND
N6	XPS insulation	663	<550	ND	-	<1	-	13.8	260	296	<330	ND	<780	ND	<180	ND
N8	XPS insulation	3,441	<570	ND	-	<1	-	3.3	<170	87	<350	ND	<810	ND	<190	ND

6. Analytical evaluation

6.1. Sampling

Samples were collected from a range of different sites including C&D waste transfer stations, soft strip sites and completed demolition sites. During sampling, several problems with material classification were identified. Firstly, it was often impossible to determine if an item of waste was from construction or demolition, and determining the age of a sample was not usually feasible. Secondly, due to the fragmented nature (broken pieces off a larger item) of some samples, it was difficult to identify the source or category of the material hence the requirements for an “other plastic products” category.

Access to suitable sites during the period of the sampling exercise was a challenge despite contacting several national trade bodies. Finding a sufficient number of different collection sites to vary the source of the samples was challenging. As participation in this project was purely voluntary, care was taken to minimise the disturbance to site operations during sample collection as well as adhering to all health and safety protocols, however, many companies were either not interested or didn’t feel able to participate. This therefore limited some on the type of samples that could be recovered (e.g. roofing and external cladding).

Although care was taken to sub-sample a reasonable quantity of each item of waste that was collected, some were present at insufficient weights for testing beyond XRF analysis largely due to the small volumes in which they are used. This was particularly the case for expanding fillers which are light and porous, where after milling it was determined that the samples were below the weight required by a laboratory to analyse.

6.2. XRF scanning

XRF scanning provided a measure of the elemental composition of each sample which was used as the basis of sample selection for chemical screening and quantification as well as the evaluation of the effectiveness of some analytical suites, such as BFRs. XRF scanning provides a highly cost and time effective method of initially characterising the 1032 samples collected.

Multiple scans were used to reduce the impact of variation in material in an to attempt to generate a representative elemental makeup of the entire sample. However, as many of the samples did not have a flat or uniform surface, and in some cases also multiple components, the variation between scans was sometimes significant.

The impact of scan variability in terms of sample composition was pronounced in samples which were multi-component items such as painted wood. As XRF is essentially a surface-based scanning technique an elevated metal concentration may only relate to a thin layer of paint rather than the whole sample.

High readings of a single metal, particularly titanium from titanium oxide pigments, would cause the XRF to select an alternative mode to the one required to analyse plastics

(restricted materials mode is used for plastic, whereas high concentrations of metals would mean selection of the geochemical mode). If this was the case, the original results were discounted, and the most appropriate mode was manually selected. This did introduce a manual step and potential for error, but all scan data was checked by a second experienced analyst to identify any issues which could be corrected by rescanning.

6.3. Chemical Screening

Chemical screening was used as a general analytical test to provide concentration range data for a wide number of parameters on a significant proportion of the samples collected. This, along with knowledge of the substances used in the manufacture of products, informed the selection of samples for specific quantitative analysis.

During the second batch of screening no CPs were initially detected. Upon further investigation it was established that this was due to a change in the analytical approach which involved the use of a different sample container. This highlights the sensitivity of these analytical methods. The samples were retested, however only concentrations above 1,000 mg/kg were reported, with concentrations that were detected but below 1,000 mg/kg not reported. As a result, additional samples were included in the CPs quantitative analysis.

In the second batch, long chained chlorinated paraffins (LCCPs) were also included in the screening suite, and the results are available in the accompanying spreadsheet database. However, since LCCPs are not classified with any hazard statement codes, they have not been included in the results presented.

6.3.1. Screening comparison

The effectiveness of the chemical screening has been assessed by comparing the detected concentration range reported with the quantified concentration where quantitative analysis was conducted. This can help inform the suitability of chemical screening for assessing waste classification. Each substance group has been evaluated in the sections below.

The chemical screening concentration range and quantified concentration is shown for each sample where there was a difference in the two, along with the impact to the potential classification if only chemical screening were used. In some cases, there is no impact as a substance may have no classification, or the substance may be below the associated HP threshold for the relevant hazard statement codes. However, in some cases, the difference in results may lead to a false positive (chemical screening concentration indicates a threshold exceedance which was not observed in the quantified result) or a false negative (quantitative concentration exceeds a threshold which was not within the chemical screening concentration range). False positives are highlighted in orange and false negatives in red.

Brominated flame retardants

Of the 51 samples selected for quantitative analysis 14 had concentrations which did not match the screening results for at least one parameter as detailed in Table 6.1.

Table 6.1 BFRs quantitative versus screening comparison

Sample	Category	Substance	Concentration (mg/kg)		Impact
			Screening	Quantitative	
1080	Plastics	DBDPE	>10,000	2,390	No impact
		TBBPA	<1,000	ND	
1122	Insulation	DBDPE	>10,000	ND	No impact
1240	Discarded construction materials	TBBPA-BDBPE	ND	30,100	No impact
3063	Expanding filler	BEHTBP	ND	1,670	No impact
2148	Discarded construction materials	TBBPA-BDBPE	ND	18,800	No impact
4021	Fixtures and fittings	TBBPA	>10,000	ND	Incorrect hazardous classification (false positive)
4027	Fixtures and fittings	PBDEs, excluding deca-BDE	ND	31,220	Incorrect POPs classification (false negative)
4049	Pipes	deca-BDE	<1,000	3,950	No impact
4080	Pipes	deca-BDE	<1,000	1,200	No impact
		TBBPA-BDBPE	<1,000	10,400	No impact
4095	Discarded construction materials	TBBPA-BDBPE	<1,000	39,200	No impact
4102	Plastics	deca-BDE	1,000 - 10,000	11,500	No impact
N6	Insulation	deca-BDE	ND	260	No impact
R035	Expanding filler	BEHTBP	ND	1,610	No impact

This comparison highlights that the main apparent mismatch is with TBBPA-BDBPE, with the substance in five samples either not detected in the screening or at a concentration below 1,000 mg/kg, but with concentrations above 10,000 mg/kg measured in the quantitative analysis. Interference from other TBBPA derivatives may be the cause of error. Since TBBPA-BDBPE is not classified with any hazard statement codes, it does not impact the potential classification of these sample at the time of writing.

The most impactful difference between the two analysis results is the reported PBDEs concentration of sample 4027 (cable cover). No PDBEs were detected at any concentration in the screening analysis for this sample but the quantitative analysis provided a combined POPs classified PBDEs concentration 60 times over the POPs threshold.

Differences in results also affected the potential hazardous classification of sample 4021 (extension lead) which was identified to have a TBBPA concentration above 10,000 mg/kg in the screening but was below LOQ in the quantitative analysis. As TBBPA is classified as H350 and H410, a concentration above 10,000 mg/kg would result in the exceedance of the respective HP 10 (1,000 mg/kg) and HP 14 (2,500 mg/kg) thresholds. However, in the quantitative analysis TBBPA was not identified above LOQ (280 mg/kg) therefore the concentration in the sample would not exceed these thresholds.

All screening results for the DBDPE compound could not be provided for 170 samples due to interference. In this batch, sample 4074 foam rubber was the only sample to have been identified to contain DBDPE above LOQ (2,020 mg/kg). The compound is not classified and therefore does not affect the outcome of the study. Solubility of DBDPE is a concern and may impact the effectiveness of chemical screening as well as quantitative analysis.

The data obtained from this study would suggest that chemical screening is unlikely to be a suitable method for identifying samples that may exceed POPs or HP thresholds for BFRs.

Chlorinated Paraffins

The comparison between chemical screening and quantitative chlorinated paraffin concentrations is provided in Table 6.2. A total of 14 of the 62 samples sent for CPs quantitative analysis were found to have a concentration above 1,000 mg/kg which were not identified through chemical screening. Of these samples eight were found to contain only MCCPs above 2,500 mg/kg. As MCCPs are classified as H410 which has a HP 14 hazardous threshold of 2,500 mg/kg all eight samples would exceed this threshold.

Two samples were identified to contain only SCCPs (sample 2107 at 1,600 mg/kg and sample 5015 at 2,900 mg/kg). As SCCPs are also classified as H410 only sample 5015 would exceed the HP 14 hazardous threshold. Both samples however are above a potential future POPs threshold of 1,500 mg/kg.

Table 6.2 CPs quantitative versus screening comparison

Sample	Category	Substance	Concentration (mg/kg)		Impact
			Screening	Quantitative	
1027	Cladding and wall panels	MCCPs	ND	10,500	Incorrect hazardous classification (false negative)
1080	Plastics	MCCPs	ND	2,100	No impact
1194	Insulation	MCCPs	ND	2,800	Incorrect hazardous classification (false negative)
1201	Doors and window frames	MCCPs	ND	1,600	No impact
2107	Doors and window frames	SCCPS	ND	1,600	No impact but above future proposed POPs threshold
3083	Expanding filler	MCCPs	ND	4,700	Incorrect hazardous classification (false negative)
3105	Flooring	MCCPs	ND	1,500	No impact but above future proposed POPs threshold
4022	Adhesives and sealants	MCCPs	ND	5,500	Incorrect hazardous classification (false negative
5015	Flooring	SCCPS	ND	2,900	Incorrect hazardous classification (false negative) and above future proposed POPs threshold
5038	Rubber products	MCCPs	ND	14,200	Incorrect hazardous classification (false negative)
N12	Adhesives and sealants	SCCPs	ND	1,600	Incorrect hazardous classification (false negative) and above future proposed POPs threshold
		MCCPs	ND	18,300	
R041	Rubber products	MCCPs	ND	1,500	No impact
7035	Pipes	MCCPs	ND	10,400	Incorrect hazardous classification (false negative)
7040	Insulation	MCCPs	ND	7,600	Incorrect hazardous classification (false negative)

Finally, a single sample (N12) was found to contain both SCCPs at 1,600 mg/kg and MCCPs at 18,300 mg/kg. This difference results in a different potential hazard classification (now exceeds HP 14 hazardous threshold by MCCPs) and an exceedance of the possible future POPs threshold.

The data obtained from this study would suggest that chemical screening is not a suitable method for identifying samples that may exceed POPs or HP thresholds for chlorinated paraffins.

Phthalates

After comparing the phthalate data, 50% (25 out of 50) of the samples sent for quantitative phthalates analysis (to date) have chemical screening concentrations that do not match the quantitative concentrations including six samples where hazardous compounds were misreported. A breakdown of these six samples is provided in Table 6.3.

Phthalates are a challenging group of substances to analysis, as many have similar structure and there is a high potential for interference. In addition, due to the grouping of phthalates and the HP 10 threshold of H360 (the most common hazard statement code) being in the middle of the 1,000 to 10,000 mg/kg chemical screening concentration band, it makes it difficult to comment on the implications.

From this comparison the difference in results impacts the potential hazardous classification of two samples. However, it was more common for the chemical screening to overestimate phthalate concentrations, suggesting a higher potential number of threshold exceedances than was observed through quantification.

An additional challenge with the phthalates was the high LOQ. A number of substances have an LOQ of over 2,000 mg/kg, which is within one of the reporting bands, and therefore it cannot be determined how accurate the screening was. Additionally, one phthalate groups detected during screening included DHUMP, which was not included in the quantitative analysis suite.

As with BFRs and CPs, chemical screening is unlikely to be a suitable method for identifying samples that may exceed POPs or HP thresholds for phthalates based on the results in this project.

Organophosphate flame retardants

The chemical screening concentrations for OPFRs matched well with the quantitative concentrations. Table 6.4 indicates there are two instances of significant deviation. Based on the data obtained in this project, chemical screening of OPFRs is likely to be more accurate than any other substance investigated. However, since a number are classified as H410 which has a threshold within the 1,000 to 10,000 mg/kg band, it is of limited use without quantitative data. It can be effective in selecting samples for quantitative analysis.

Table 6.3 Phthalates quantitative vs screening comparison

Sample	Category	Substance	Concentration (mg/kg)		Impact
			Screening	Quantitative	
1065	Pipes	BBP	1,000 - 10,000	<40	Potential incorrect hazardous classification (false positive)
2066	Cladding and wall panels	DEHP/DNOP /DIOP	ND	14,450	Incorrect hazardous classification (false negative)
2107	Doors and window frames	DEHP/DNOP /DIOP	ND	7,360	Incorrect hazardous classification (false negative)
2179	Flooring	DIHP	1,000 - 10,000	<50	Potential incorrect hazardous classification (false positive)
5015	Flooring	DIHP	1,000 - 10,000	<40	Potential incorrect hazardous classification (false positive)
R047	Flooring	DIHP	1,000 - 10,000	<40	Potential incorrect hazardous classification (false positive)
1065	Pipes	BBP	1,000 - 10,000	<40	Potential incorrect hazardous classification (false positive)

Table 6.4 OPFRs quantitative vs screening comparison

Sample	Category	Substance	Concentration (mg/kg)		Impact
			Screening	Quantitative	
1196	Insulation	TCPP	1,000 - 10,000	<220	Potential incorrect hazardous classification (false positive)
5060	Fixtures and fittings	TPP	<1,000 mg/kg	3,680	No impact *

6.4. Quantitative analysis

A number of technical challenges were encountered during quantitative analysis carried out by VU Amsterdam and The Fraunhofer institute. The overall impact of these difficulties is potential under reporting of BFRs linked to “unaccounted for” bromine, based on pre and post extraction XRF scanning, often alongside antimony. However, despite bromine being detected using XRF, no BFRs were found during quantitative testing. Furthermore, high LOQs, particularly for phthalates and BFRs reduces the certainty that classified substances were present below relevant POPs or HP thresholds. These challenges include the following, which are discussed in further detail in the sections below.

- Extraction from foam samples.
- Quantification of HBCD.
- Quantification of insoluble BFRs.
- Presence of alternative BFRs.
- Thresholds of quantification and sample dilution.
- Background concentrations and contaminants.

6.4.1. Extraction from foam samples

A number of samples were composed of a porous material, such as foam insulation. Analysis of this type of material is challenging, as it is difficult to recover all of the solvent post extraction, leading to a potential under reporting of substances due to residual solvent being left behind which may contain target substances. If a more aggressive extraction process is used, it risks dissolving too much of the polymer matrix, which will then lead to a higher-level interference during quantification. The implication of this is that concentrations of substances, particularly BFRs, maybe be under reported by laboratories in some matrices.

6.4.2. Quantification of HBCD

Quantification of HBCD was reported to be a challenge by the Fraunhofer Institute. In the single sample found to contain HBCD, a quantified result was not possible and instead was reported as containing over 700 mg/kg.

Fraunhofer have previously identified that the analysis of HBCD can be problematic in some matrices, with low recoveries observed. Initially this was thought to be linked to thermal destruction during injection into the mass spectrometer. The Fraunhofer Institute have undertaken considerable method development over the last year and believe this method has now been optimised in this respect. VU Amsterdam also do not believe HBCD will be destroyed during injection, however it may be an issue faced by some laboratories.

Despite this, it was still not possible to quantify HBCD. Spiking with an internal standard still results in a lower recovery than expected for the matrices relevant to this study. It is now considered that this is due to interferences from other flame retardants, particularly

TBBPA derivatives. In an interlaboratory trial testing programme with a testing facility in Japan, it was found that HBCD recoveries were highly dependent on the matrix.

If present, HBCD should be detected in quantitative analysis, but it may not be possible to accurately quantify this substance and use of internal standards to have knowledge of recovery issues is key. This could become more problematic if the POPs threshold is reduced.

6.4.3. Quantification of insoluble BFRs

Decabromodiphenyl ethane (DBDPE) was the initial favoured replacement for deca-BDE and has been in use since the 1990s. It has a similar chemical structure to deca-BDE, but a particular challenge is that it is virtually insoluble in the selection of available solvents used for FR analysis. As a result, this means that although the presence of DBDPE can be identified, only a semi-quantitative analysis is possible. This is especially pronounced in foams, where there is already a challenge in quantifying substances caused by loss of the extraction solvent and matrix interference.

The use of a stronger solvent may lead to higher extraction efficiencies but to the detriment of quantification, as this will dissolve more of the matrix and lead to higher analytical interference. Dilution to reduce matrix issues would then have a corresponding impact on the threshold of detection and quantification.

Polymeric flame retardant (PolyFR) is a block copolymer of polystyrene and brominated polybutadiene. It is therefore a very large molecule (in comparison to other BFRs) and has proven to be impossible to extract and quantify using existing methods. The presence of DBDPE and PolyFR may account for high pre and post extraction XRF scanning i.e. bromine has been identified at high concentrations, but it is not currently possible to release these substances from the matrix during extraction. It is therefore challenging to know if a low extraction is due to the presence of insoluble FRs, difficulties in quantification in the test matrix due to interferences or due to other inefficiencies in some test laboratory processes.

6.4.4. Presence of alternative BFRs

Only BFRs included in the analytical suites have been identified and quantified. It is entirely possible where XRF scanning shows a high extraction was achieved, but quantification only identifies low concentrations of the targeted substances that alternative soluble BFRs may be present. Specifically, work completed by the Fraunhofer Institute suggests the increasing use of TBBPA derivatives which seem to be interfering with the quantification of primary TBBPA. It is believed these derivatives are being manufactured and used in significant quantities in Asia. One of these derivatives, TBBPA-BDBPE, was included in the VU Amsterdam suite and it was quantified in five samples at levels over 10,000 mg/kg.

As the number of different BFRs with marginally different chemical structures increases, it will make quantitative analysis ever more complicated. This could be especially

problematic when the manufactured products of today become tomorrow's waste. It is essential that expert laboratories continue to develop their analytical methods to keep them current. A significant problem is the scarcity of information on new chemical use and the lack of available reference standards and certified reference materials to support development and validation of analytical methods. Method development also comes at a significant cost and can only be justified in the commercial laboratory sector when predicted sample throughput supports this initial outlay.

6.4.5. Limits of quantification

This project involved the analysis of discrete items of waste, typically of a single material. As such, there was the potential for target substances to be present at very high levels (i.e. over 10% by mass). The analytical techniques used are highly sensitive, and analysing materials with such high concentrations can overwhelm the analytical equipment. In addition, the samples would often have non-target substances in the polymer matrix which were also extracted. This can cause interference in quantification, but also contaminates the chromatography column and injection system, resulting in machine downtime and additional cost for equipment decontamination. A further complication is that some target substances may be present at much lower functional concentrations than others e.g. phthalates versus BFRs.

One method used to combat this is to dilute the extract containing the target substance with additional solvent. The results from the mass spectrometer can be scaled to calculate the concentration in the sample accounting for the dilution. This works well for a substance that is present at high levels, however it also raises the threshold of detection and therefore the limit of quantification. The result of this is that it may prevent quantification of substances present at significantly lower concentrations than the target substance.

In most cases, it is still possible to achieve an LOQ that is below the associated classification threshold, however in particularly complex materials, such as foam materials in the discarded construction material category, dilution rates may need to be so high that the LOQ is above target thresholds.

6.4.6. Background concentrations

To calculate the LOQ, blanks are run alongside the samples. Blanks are prepared in the same way as the sample extracts i.e. they are subjected to the entire extraction procedure, but without any sample material. This is done to detect any background or trace concentrations of the target substances which may be associated with the chemicals or equipment used or analytical carry-over when samples have target parameters present at significantly different concentration ranges. Reported sample concentrations would normally be blank corrected unless unacceptable levels of cross-contamination are identified. In this case sample re-extraction and quantification would be required.

This issue is particularly relevant to the quantification of phthalate concentrations in the C&D waste stream. Due to widespread use, phthalates are commonly present at concentrations well above background levels, and following a necessary dilution, the result

is a high phthalate LOQ. This was the case for a number of phthalates including DEHP/DIOP, which typically had an LOQ of 2,000 mg/kg. These substances are classified as H360 which have a hazardous threshold of 3,000 mg/kg for HP 10. Although the LOQ is below the threshold, for quantitative analytical data for waste samples, where errors can arise at many points in the process, it is difficult to use this to conclude beyond reasonable doubt that test samples would not exceed this threshold. Further work would be needed to develop an approach to separate target substance groups with additional clean-up techniques. With the list of chemicals of interest expanding, the impact of quantifying very different concentration bands will be ever more complex and will have an impact on the LOQ for lesser concentration substances.

In the quantitative phthalate analysis concentrations of Bis(2-ethylhexyl) sebacate were observed between 2,000 and 4,000 mg/kg. This non-phthalate plasticiser was quantified in this range in all samples tested. VU Amsterdam believe that this is a contaminant from equipment used to prepare or contain samples and has not been included in the analysis.

6.5. Additional challenges and limitations

In addition to the specific challenges associated with analysis, it is worth identifying some additional constraints and difficulties.

6.5.1. Limitation of XRF scanning

XRF scanning provides a rapid, low-cost analysis of samples to determine a semi-quantitative concentration for key elements. The method is however a surface analysis method, and therefore if a product has a coating, or is made from several materials bonded together, it does not give a representative concentration of the sample as a whole i.e. to full depth. Quantitative analysis carried out on a sample that has been cryogenically milled to less than 1 mm will incorporate the surface and inner structures in the correct ratios, and therefore XRF and quantitative data may not always match as expected.

This can be particularly problematic when a flame retardant or paint containing a heavy metal is only applied as a surface coating, as XRF will indicate a potential hazardous or POP threshold exceedances (as determined by marker compounds) which may not be accurate.

6.5.2. Characterisation of the C&D waste stream

Construction and demolition waste is a significant waste stream in the UK, however, it is also very varied with a large quantity of inert materials being disposed or recovered alongside ex-products which have a multitude of functions. This variability in the waste makes characterisation of the whole stream a challenge.

The selected approach required for this study, which included targeting certain categories down to specific types of a product (e.g. EPS and XPS insulation) means that the results cannot be extrapolated to represent an entire product category or the overall C&D waste stream as sampling was not proportional to the overall waste arisings identified at the sampling sites or the waste stream as a whole.

A further limitation was the potentially subjective nature of categorisation, even with an experienced team, there was a challenge to fully categorise fragments of products of unknown origin. At sites accepting construction and demolition waste e.g. waste transfer stations, it becomes very difficult to distinguish between new and old materials. Even where samples were taken from soft strip demolition, commercial sites have often been subjected to multiple ‘refits’ which makes identifying age difficult. We consider that for the most part there is little value in comparing the collected samples in terms of construction. An exception would be relatively short life products such as protective flooring sheets and buckets which will provide an indication of ‘recent’ construction waste. However, as several samples were new products these do provide a valuable indicator of the use of flame retardant chemicals in the current marketplace.

The results can be used for further targeted studies, to:

- highlight the potential classified substances present
- understand in more detail the potential impact of changes to POPs thresholds (specifically in SCCPs) and the addition of substances to the Stockholm Convention (specifically MCCPs).

6.5.3. Laboratory capacity constraints

This project included chemical screening and a wide suite of quantitative analysis on a broad range of waste types. The breadth of the analytical testing required restricted the number of laboratories who were capable of completion of testing. Commercial laboratories, although often able to offer chemical screening and quantitative analysis are typically unable or unwilling to provide detailed information on analytical methods. Without this level of detail and confidence in the methodologies, the commercial laboratories cannot be used for these types of studies as method validation and performance cannot be checked.

This necessitates the use of universities and research institutes. The limitation here is that typically the institute will specialise in a narrow range of substance quantification. Additionally, these institutes commonly do not have the same focus on sample turnaround and reporting as commercial laboratories. The personnel carrying out the analysis at institutes are highly competent and indeed are commonly able to undertake new method changes concurrent with testing, but they are not set up for delivering test results in a timely fashion for large number of samples even where analytical slots have been pre-booked.

Therefore, although the quality of analysis received from institutes is high, relying on them to carry out large numbers of tests can lead to delays. Developing the capabilities of commercial laboratories would enable more routine analysis of waste samples. However, the ever-expanding list of potential chemicals of interest in an ever-growing list of matrices will make balancing the needs of bespoke versus routine testing difficult.

7. Conclusions

This study provides a baseline data set for the concentrations of a range of substances classified as POPs or with hazard statement codes in a comprehensive range of construction and demolition waste. The analytical programme was staged, with initial XRF scanning of all samples, followed by targeted chemical screening and quantitative analysis. XRF analysis was used to make some adjustments to the number of samples collected in some construction and demolition categories. This has enabled a broad characterisation of the different products and more targeted analysis of categories which were prioritised following XRF and chemical screening.

Due to the mixed nature of many C&D waste collection systems it is difficult to accurately gauge whether target materials are construction or demolition. It is also difficult to gauge the age of the material as articles are often incomplete and do not contain labels that would point to a place of manufacture or date of production.

It is possible to make a number of observations from the data generated as part of this study.

- For the POPs classified substances included in the analytical suites, only PBDEs (11 samples) and SCCPs (one sample) were found at concentrations above current thresholds.
- A reduction in the SCCPs threshold from 10,000 mg/kg to 1,500 mg/kg would increase the number of samples with an SCCPs POP threshold exceedance from one sample to 11.
- Listing of MCCPs under the Stockholm Convention would impact the POPs classification, particularly for expanding fillers and foam rubber insulation.
- Dechlorane plus and PFAS were not detected in any samples above the limit of quantification (LOQ), suggesting these substances are unlikely to be present at significant concentrations in most waste streams.
- Classified organophosphate flame retardants (OPFRs) were more abundant than brominated flame retardants (BFRs) in concentrations exceeding HP thresholds for associates hazard statement codes. OPFRs were present primarily in expanding fillers and fixtures and fittings.
- Products made from PVC were found to have high levels of lead through XRF scanning. Although the exact compound was not identified or quantified, it is likely a significant proportion of this waste stream has concentrations exceeding HP thresholds.
- Products made from rubber have been shown to contain zinc, likely as zinc oxide, above relevant HP thresholds.
- There is strong evidence to suggest that POPs classified substances are currently still being added during manufacture in some parts of the world and in a similar vein, short-life construction materials such as buckets, barriers and cones are being made from POPs containing polymer recyclate.
- Quantitative analysis of these products is very challenging due to

- the range of very different polymer matrices
- the number of different substances/additives present which can lead to interference,
- the potential for high concentrations of some substances which necessitates dilution to avoid overload of sensitive instrumentation. This means that substances present at much lower concentrations are diluted below the LOQ.
- the challenge in extracting substances from foams

Drawing a concise conclusion from the data generated in this project is challenging, as both the sampling and analysis procedure was targeted at products suspected of containing relevant classified substances. This is therefore not a true reflection of the composition of the overall C&D waste stream. It does however provide a strong starting point for waste producers, managers and regulators, to consider which materials may contain hazardous substances and how to address this in future to classify waste correctly.

Appendix A – Analytical Methods

A1 XRF

X-ray fluorescence is based on the excitation of atoms in a test sample, for example antimony. A primary X-ray, typically generated in an X-ray tube, hits an inner shell electron of an elemental atom causing its ejection. The open position is filled by an electron from a further outer shell and fluorescence radiation is emitted. The fluorescence energy is equal to the energy difference between the two electron shells. The energy of this radiation is unique to the atom and can therefore be used at an atomic level to identify elements that are present. In an energy dispersive XRF instrument, fluorescence radiation is detected using a semi-conductor with the signals are collated in a multi-channel-analyser.

The detector of a modern XRF machine can handle 1 million counts (signals) per second. Even with a short measurement time, the spectrum can give sufficient information to calculate intensities, which can be used to estimate the composition of the sample. Using a longer measurement time allows for better statistics resulting in better precision and better peak-to-background ratios, thus resulting in improved detection thresholds.

As a minimum a few million counts should be collected for the accurate determination of the presence of an element. Collection of fewer counts (linked to the time over which data is accrued) is possible where concentrations are high but where concentrations are low and specifically close to the threshold of detection an increased ‘scan’ time should be used.

XRF analysis was undertaken at the WRc laboratory using a Bruker S1 Titan handheld X-Ray fluorescence (XRF) analyser. This instrument has specific calibration programmes including ‘restricted materials’ for the analysis of elements in plastic/polymers. Previous XRF scanning experience by WRc has shown a scan time of 30 seconds is sufficient to provide reliable XRF data with a good threshold of detection for different types including WEEE polymer of varying density and textiles used in soft furnishings.

The level of detection is different for each element within different materials. Therefore, a fixed value was applied as the level of detection concentration (in mg/kg) for each element based on the average level of detection for the instrument and based on the lowest concentrations detected during scanning of all samples. The threshold of detection (LOD) value is different for each element within different sub-modes. Therefore, for statistical analysis a fixed value was applied as the LOD for each element based on the lowest value recorded buy the instrument. The LOD values applied during the data analysis are outlined in Table A.1.

Table A.1 XRF Threshold of detection

Element	LOD (mg/kg)
Aluminium (Al)	260
Chlorine (Cl)	41
Titanium (Ti)	6
Vanadium (V)	1
Nickel (Ni)	6
Zinc (Zn)	2
Arsenic (As)	3
Bromine (Br)	1
Cadmium (Cd)	12
Tin (Sn)	9
Antimony (Sb)	18
Barium (Ba)	24
Lead (Pb)	4

XRF analysis is a -semi-surface technique, and the depth to which the X-ray beam penetrates is dependant on a number of factors, including the composition of the sample itself. Therefore, the X-ray beam can penetrate to varying degrees which can introduce a factor of variability. This is particularly significant for the analysis of chlorine which is likely to be present at high concentrations in a PVC material. Therefore, if the beam penetration depth is variable it is possible that a determined concentration may vary between scans as a direct result of the X-ray beam penetration depth. Additionally, porous material such as foams can present a challenge for analysis as the empty pores serve to articifially reduce determined concentrations. In order to minimise under reporting of concentrations in highly porous materials the samples were compressed using a 4-tonne hydraulic press ahead of XRF analysis.

Where a determined concentration of an element was below the level of detection, it was assumed to be at the level of detection, e.g. for bromine al '< LOD' values were noted to be 2 mg/kg for statistical analysis. This is a 'worst-case' approach. It should be noted that the LOD concentration values for each element are typically at least one factor below the most stringent concentration/threshold thresholds for a POPs waste asessment and therefore this approach would not affect the outcome of any assessment. For example, where antimony may be present as antimony trioxide HP assessment cut-off and concentration thresholds are 1,000 mg/kg and 10,000 mg/kg. Therefore an assumption that concentrations below LOD values are present at 18 mg/kg would have negligible impact on the assessment. There were no instances in the data analysis where a concentration was within 10 mg/kg of a cut-off, concentration threshold or threshold threshold.

A2 Chemical Screening

Pre-milled samples (25 mg) were first extracted with dichloromethane (0.8 ml), followed by sonication, shaking (12 h) and centrifugation. The supernatant was collected, and the sample reextracted with toluene (0.8 ml), and the extracts were combined. The combined extract was evaporated under nitrogen (30ºC) and finally dissolved in 1 ml toluene. This extract was diluted 1000x as the concentrations of some chemical additives were very high in the tested samples. Therefore, samples had to be diluted to a final concentration that did not overload the LC column and the mass spectrometer. In some instances, a dilution of 10,000 times was required.

Screening analysis was performed by liquid chromatography with high resolution mass spectrometry (LC-QTOFMS, mass resolution 25000) using positive mode for the phthalates and OPFRs, and negative mode for UV-328. A C18 column with water and methanol was used for the separation of the compounds. Screening of BFRs, SCCPs, and MCCPs was conducted with LC-APCI-QTOFMS (mass resolution 25000) in negative mode. For the BFR screening, methanol and water were used as the LC gradient, and for SCCPs and MCCPs acetonitrile, and dichloromethane as a dopant.

Identification of the chemicals was based on the exact mass and isotope patterns and the comparison with analytical standards. The confidence level of identification is level 4 according to the scheme of Schymanski et al. 2014. The LOD for the screening was approximately 1,000 mg/kg however, the exact LOD of the sample depended on the sample matrix and the response factors of the standards in the mass spectrometer.

Tables A.2 to A.5 provides the full list of substances included in the chemical screening suites.

Table A.2 Phthalate screening compounds

Acronym	Compound Name
Phthalates	
DBP	Dibutyl phthalate
DIBP	Diisobutyl phthalate
BBP	Benzyl butyl phthalate
DIPP	Di-isopentyl phthalate
DPP	Di-n-pentyl phthalate
NPIPP	n-pentyl-isopentyl phthalate
DHP	Dihexyl phthalate
DINP	Diisononyl phthalate
DHUNP	Di-C7-11 alkylphthalates, branched and unbranched
DIHP	Di-isoheptyl phthalate

Acronym	Compound Name
DEHP	Bis(2-ethylhexyl) phthalate
DNOP	Di-n-octyl phthalate
DIOP	Di-iso-octyl phthalate
DIDP	Diisodecyl phthalate
Phthalate substitutes	
DINCH	Di(isononyl) cyclohexane-1,2-dicarboxylate
ATBC	Tributyl acetyl citrate
DEHA	Bis(2-ethylhexyl) adipate
DOA	Di-n-octyl adipate
DOS	Bis(2-ethylhexyl) sebacate
TOTM	Tris(2-ethylhexyl) trimellitate

Table A.3 Brominated screening compounds

Acronym	Compound Name
Brominated flame retardants	
HBCD	Hexabromocyclododecane
PBDE, excl Deca-BDE	All PBDE substances excluding Deca-BDE
Deca-BDE	Decabromodiphenyl ether (BDE-209)
TTBP-TAZ	Tris(2,4,6-tribromophenoxy)-1,3,5-triazine
2,4,6-TBP	2,4,6-Tribromophenol
HCDBCO	Dibromocyclooctane
BEHTBP	bis(2-ethylhexyl) tetrabromo phthalate
TBBPA-BDBPE	Tetrabromobisphenol A Bis(2,3-dibromopropyl) ether
TBBPA	Tetrabromobisphenol A
TBBP-S	Tetrabromobisphenol S
TDBP TAZTO	Tris (2,3-dibromopropyl) isocyanurate
BTBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane
DBDPE	Decabromodiphenyl ethane
EHTBB	2-Ethylhexyl-2,3,4,5-tetrabromobenzoate

Table A.4 Phosphate screening compounds

Acronym	Compound Name
TCEP	Tris (2-Chloroethyl) Phosphate
TCPP	Tris (1-chloro-2-propyl) phosphate
TDCIPP	Tris(1,3-dichloro-2-propyl)phosphate
TPP	Triphenyl phosphate
BDP	Bisphenol A bis(diphenyl Phosphate)
RDP	Resorcinol bis(diphenyl phosphate)
TDBP	Tris(2,3-dibromopropyl) phosphate
TNBPP	Tributyl phosphate
TCP	Tricresyl phosphate

Table A.5 Other screening compounds

Acronym	Compound Name
Chlorinated paraffins	
SCCPs	Short-chain chlorinated paraffins
MCCP	Medium-chain chlorinated paraffins
Other POPs compounds	
DCP	Dechlorane Plus
UV-328	Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylpropyl)

A3 Quantitative Analysis – Vrije Universiteit Amsterdam

The extracts from the chemical screening analysis (see above section) were used for quantitative analysis with the relevant isotope labelled internal standards added, as shown in Table A.6.

Table A.6 Internal standards used by VU

Analytical suite	Internal standard
BFR + DCP	^{3}C-DBDPE, ^{13}C-TBBPA, ^{13}C-TTBP-TAZ, ^{13}C-Deca-BDE, ^{13}C-HBCD,
CPs + DCP	^{13}C-Dechlorane Plus*
Phthalates + UV328	d4-DnBP, d4-DEHP, d8-Bis(2-ethylhexyl)adipate
OPFRs	d12-TCEP, d18-TPHP
PFAS	Labelled PFAS

*Currently 13C labelled CPs are available and VU are evaluating how well these work

All analysis (aside from CPs and PFAS) was performed using LC-QToFMS (Compact, Bruker, mass resolution 25000), in negative mode for BFRs, dechlorane plus, and UV328, and in positive mode for. phthalates. For the analysis of phthalates, a delay LC column (Isolator column 2.1 x 50 mm, Waters), and an analytical column (Xbridge BEH C18 2.1 x 100 mm, 2.5 µm, Waters) were used.

PFAS were analysed by LC-MS/MS (6500+, Sciex) in negative mode. External calibration (7 calibration points) was performed for the quantification. PFAS were analysed by a RP18 BEH Shield column (Xbridge, 100 x 2.1 mm, 2.5 µm, Waters) by applying a gradient of ammonium acetate in water (MiliQ) and methanol.

External calibration (7 calibration points) was performed for the quantification. For quantification the [M-H]- ions were taken for PFAS, [M+H]+ for phthalates and OPFRs, and for BFRs [M-H] - or [M-Br+O]- ions. Limit of detection (LOD) was calculated based on the lowest calibration point or the blank value, and the limit of quantification (LOQ) is 3x the LOD

Tables A.7 to A.9 provide the list of substances included in the quantitative analytical suites. The OPFRs suite was identical to the chemical screening suite (Table A.4).

SCCPs and MCCPs were analysed by chlorine-enhanced APCI time-of-flight high resolution mass spectrometry (APCI-TOF-HRMS, mass resolution 25000) using acetonitrile and dichloromethane as dopant. Quantification was performed according to the deconvolution method described in Brandsma et al. (2017; 2019), using external calibration with a range of SCCPsor MCCPs mixtures.

Procedural blanks were included to reveal any contamination during handling, and sample preparations. As expected, phthalates were found in the procedure blanks as phthalates are present in trace levels in extraction solvents and are also present in the air. For some phthalates the limit of detection is therefore higher than for others. Quantification was performed with external calibration using analytical standards, and concentrations were corrected for internal standards. Mean recoveries of the internal standards for the phthalates were 79%, BFRs 101%, CPs 81%, and OPFRs 102%.

Table A.7 Phthalate quantitative suite

Acronym	Compound Name
Phthalates	
DBP	Dibutyl phthalate
DIBP	Diisobutyl phthalate
BBP	Benzyl butyl phthalate
DIPP	Di-isopentyl phthalate
DPP	Di-n-pentyl phthalate
DHP	Dihexyl phthalate
DINP	Diisononyl phthalate
DIHP	Di-isoheptyl phthalate
DEHP	Bis(2-ethylhexyl) phthalate
DNOP	Di-n-octyl phthalate
DIOP	Di-iso-octyl phthalate
DIDP	Diisodecyl phthalate
Phthalate substitutes	
DINCH	Di(isononyl) cyclohexane-1,2-dicarboxylate
ATBC	Tributyl acetyl citrate
DEHA	Bis(2-ethylhexyl) adipate
DOA	Di-n-octyl adipate
TOTM	Tris(2-ethylhexyl) trimellitate
UV-328	
UV-328	Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylpropyl)

Table A.8 Brominated flame retardant quantitative suite

Acronym	Substance
HBCD	Hexabromocyclododecane
tetra-BDE	Tetrabromodiphenyl ether
penta-BDE	Pentabromodiphenyl ether
hexa-BDE	Hexabromodiphenyl ether
hepta-BDE	Heptabromodiphenyl ether
deca-BDE	Decabromodiphenyl ether (BDE-209)
TTBP-TAZ	Tris(2,4,6-tribromophenoxy)-1,3,5-triazine
2,4,6-TBP	2,4,6-Tribromophenol
HCDBCO	Dibromocyclooctane
BEHTBP	bis(2-ethylhexyl) tetrabromo phthalate
TBBPA-BDBPE	Tetrabromobisphenol A Bis(2,3-dibromopropyl) ether
TBBPA	Tetrabromobisphenol A
TBBP-S	Tetrabromobisphenol S
TDBP TAZTO	Tris (2,3-dibromopropyl) isocyanurate
DBDPE	Decabromodiphenyl ethane
EHTBB	2-Ethylhexyl-2,3,4,5-tetrabromobenzoate
DCP	
DCP	Dechlorane Plus

Table A.9 PFAS quantitative compounds

Acronym	Substance
PFBA	Perfluoro-n-butanoic acid
PFPeA	Perfluoro-n-Pentanoic acid
PFHxA	Perfluoro-n-hexanoic acid
PFHpA	Perfluoro-n-hePtanoic acid
PFOA	Perfluoro-n-octanoic acid
PFNA	Perfluoro-n-nonanoic acid
PFDA	Perfluoro-n-decanoic acid
PFUnDA	Perfluoro-n-undecanoic acid
PFDoDA	Perfluoro-n-dodecanoic acid
PFTrDA	Perfluoro-n-tridecanoic acid
PFTeDA	Perfluoro-n-tetradecanoic acid

Acronym	Substance
PFBS	Perfluoro-1-butane sulfonic acid
PFPeS	Perfluoro-1-Pentane sulfonic acid
PFHxS	Perfluoro-1-hexane sulfonic acid
PFHpS	Perfluoro-1-heptane sulfonic acid
PFOS	Perfluoro-1-octane sulfonic acid
PFNS	Perfluoro-1-nonane sulfonic acid
PFDS	Perfluoro-1-decane sulfonic acid
42FTS	4:2 Fluorotelomer sulfonic acid
62FTS	6:2 Fluorotelomer sulfonc acid
82FTS	8:2 Fluorotelomer sulfonic acid
102FTS	10:2 Fluorotelomer sulfonic acid
FOSA	Perfluoro-1-octanesulfonamide
MeFOSAA	N-Methylperfluorooctane sulfonamidoacetic acid
EtFOSAA	N-Ethylperfluorooctane sulfonamidoacetic acid
MeFBSAA	N-Methylperfluorobutane sulfonamidoacetic acid
MeFHxSAA	N-Methylperfluorohexane sulfonamidoacetic acid
HFPO-DA	Hexafluoropropyleneoxide dimer acid
DONA	Dodecafluoro-3H-4,8-dioxanonanoate
9ClPF3OUdS	9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate
11ClPF30UdS	11-Chloroeicosafluoro-3-oxaundecane-1-sulfonate
8:2FTUCA	2H-Perfluoro-2-decenoic acid

The department of A-LIFE of the Vrije Universiteit Amsterdam (The Netherlands) has organised and participates in various interlaboratory studies for many different environmental pollutants (e.g. PCBs, PBDEs, OPFRs, CPs) analysis together with the WEPAL-QUASIMEME programme. In addition, to the WEPAL_QUASIMEME interlaboratory studies VU also participated in the EURL POP interlaboratory studies, NORMAN interlab studies, and studies organised by NIES (Japan) on polymer materials. NIES organized two interlab studies on BFRs, including BDE209, in plastic waste, and one on CPs in plastic waste materials. In these three NIES interlab studies for PBDEs and CPs VU had Z-scores of <1. In addition, CRM and ERMs materials were analysed: CRM-PVC001 (PVC material) the recovery of phthalates was 120%, ERM-EC591 (PP material) BDE209 Z-score was 1.3, and ERM-EC590 (PE material) BDE209 Z-score was 1.0. For ERM-EC591 VU participated in the certification of the material.

A4 Quantitative Analysis – Fraunhofer Institute

The method used by Fraunhofer (IVV Methode PA 1_633) is no longer accredited due to a number of changes in the analytical method, however the quality of the data is considered to be high and the changes carried out were made to improve upon the accuracy.

A 0.1 g sample of the material was weighed into 20 ml glass vials together with 10 ml toluene. The extraction was carried out for 24 h at 60°C. Most of the extracts were only filtrated whereas some of them, in which the sample matrix was partially or completely dissolved in the solvent, underwent further clean-up steps. To these extracts 40 ml of ethanol was added. The resulting precipitated sample matrices were also removed by filtration. The filtrate was then evaporated to 5 ml and then filled up with toluene to an end volume of again 10 ml. The internal standard (13C- labelled PBDEs) was added to an aliquot of the filtrated solution.

The analysis was carried out via GC-MS (QP2010-MS, Shimadzu) in SIM-Scan mode. The target substances were identified through known mass fragments in the SIM mode. The quantification was done by external calibration and secured by use of mass-labelled internal standards. In the case of Decabromodiphenylethane (DBDPE) no adequate external standard substance was available due to solubility issues. Therefore, the calibration standards of deca-BDE was used for a semi-quantitative approach. TBBPA and HBCD were quantified with internal standard substances through spiking experiments. Table A.10 provides the GC parameters and A.11 the MS parameters used by Fraunhofer.

Table A.10 GC instrument parameters

Temperature program	120°C (2 min) – 30°C/min – 230°C (5.5 min) – 20°C/min – 340°C (3 min)
Carrier gas	Helium
Column Flow	1.35 ml/min (constant flow)
Injector temperature	300°C
Injection mode	Splitless
Injection volume	2 µl
Column	Rtx-5MS, 14.5m x 0.1 µm x 0.25 mm

Table A.11 MS instrument parameters

Substance	Retention time [min]	m/z target ion	m/z reference ion
BDE17	5.410	248.00	406.00
BDE28	5.510	248.00	406.00
BDE28L	5.510	260.00	418.00
BDE49	6.200	326.00	486.00

Substance	Retention time [min]	m/z target ion	m/z reference ion
BDE71	6.250	326.00	486.00
BDE47	6.380	326.00	486.00
BDE47L	6.380	338.00	498.00
BDE79L	6.450	498.00	338.00
BDE66	6.530	326.00	486.00
BDE77	6.810	326.00	486.00
BDE100	7.430	404.00	563.00
BDE100L	7.430	416.00	575.00
BDE119	7.560	404.00	563.00
BDE99	7.840	404.00	563.00
BDE99L	7.840	416.00	575.00
BDE85	8.770	404.00	563.00
BDE126	8.950	563.00	404.00
BDE126L	8.950	575.00	416.00
BDE154	9.430	643.00	484.00
BDE154L	9.430	655.00	496.00
BDE153	10.510	643.00	484.00
BDE153L	10.510	655.00	496.00
BDE138	12.000	643.00	484.00
BDE138L	12.000	496.00	655.00
BDE156	12.400	643.00	484.00
BDE184	12.790	561.00	721.00
BDE183	13.080	721.00	561.00
BDE183L	13.080	733.00	573.00
BDE191	13.480	561.00	721.00
BDE204	14.580	641.00	801.00
BDE197	14.590	641.00	801.00
BDE197L	14.590	653.00	813.00
BDE196	14.830	641.00	801.00
BDE207	15.840	719.00	361.00
BDE207L	15.840	731.00	367.00
BDE206	16.030	719.00	361.00
BDE206L	16.030	731.00	367.00
BB209	16.270	783.00	623.00

Substance	Retention time [min]	m/z target ion	m/z reference ion
BB209L	16.270	795.00	635.00
BDE209	16.920	799.00	801.00
BDE209L	16.920	811.00	813.00
HBCD	11.440	239.10	236.80
TBBPA	10.590	529.00	544.00
DBDPE	17.670	811.00	495.70

The limits of detection were estimated through the smallest detectable calibration standards. Regarding the weighed portion of the sample and the dilution factor of extraction and precipitation the detection limits range from 250 ng/g (Tetra- and PentaBDE) and 500 ng/g (Hexa-, Hepta- and OctaBDE) to 2500 ng/g (Nona- and DecaBDE) in the sample material.

Table A.12 provides the full list of substances included in the Fraunhofer analytical suite.

Table A.12 Full list of substances quantified by Fraunhofer

Substance	Acronym	Congener
Monobromodiphenyl ether	Mono-BDE	BDE 3
Dibromodiphenyl ether	Di-BDE	BDE 7 and BDE 15
Tribromodiphenyl ether	Tri-BDE	BDE 17 and BDE 28
Tetrabromodiphenyl ether	Tetra-BDE	BDE 47, BDE 49, BDE 66, BDE 71 and BDE 77
Pentabromodiphenyl ether	Penta-BDE	BDE 85, BDE 99, BDE 100, BDE 119 and BDE 126
Hexabromodiphenyl ether	Hexa-BDE	BDE 138, BDE 153, BDE 154 and BDE 156
Heptabromodiphenyl ether	Hepta-BDE	BDE 183, BDE 184 and BDE 191
Octabromodiphenyl ether	Octa-BDE	BDE 196 and BDE 197
Nonabromodiphenyl ether	Nona-BDE	BDE 206 and BDE 207
Decabromodiphenyl ether	Deca-BDE	BDE 209
Tetrabromobisphenol A	TBBPA	-
Decabromodiphenyl ethane*	DBDPE	-
Hexabromocyclododecane	HBCD	-

*Semi-quantitative

A5 Quantitative analysis – Marchwood Scientific Services

Each sample was analysed by MSS using High Resolution GC/MS – Isotope Dilution (USEPA 1668). A 1 g aliquot of each sample was taken from the <1 mm powder prepared by WRc and was extracted using Soxhlet extraction, using hexane as a solvent over 20 hours. The sample was spiked with an internal standard mixture (18 PCB congeners) and analysed, allowing recovery rates to be calculated for the dl-PCBs and the ICES6 PCBs. The LOQ for the 209 PCBs was 0.33 ng/kg, but for the individual PCBs quantified the LOQ varies. The TEQ for the dl-PCB concentration has been calculated using World Health Organisation (WHO) 2005 and 2022[13] TEFs. A list of the standards used in the analysis is provided in Table A.13

Table A.13 Internal standards

Substances		
PCB-81	PCB-126	PCB-28
PCB-77	PCB-167	PCB-52
PCB-123	PCB-156	PCB-101
PCB-118	PCB-157	PCB-153
PCB-114	PCB-169	PCB-138
PCB-105	PCB-189	PCB-180

The quantification was undertaken in three distinct sections as outlined in Table A.14

Table A.14 Substances quantified by MSS

Substance	Acronym	Congener
Dioxin like PCBs	dl-PCB	PCB-81, PCB-77, PCB-123, PCB-118, PCB-114, PCB-105, PCB-126, PCB-167, PCB-156, PCB-157, PCB-169, PCB-189
Non-dioxin like PCBs	ICES6	PCB 28, PCB 52, PCB 101, PCB 153, PCB 138, PCB 180
Total PCBs	PCB Sum of 209	MonoCB, DiCB, TriCB, TetraCB, PentaCB, HexaCB, HeptaCB, OctaCB, NonaCB, DecaCB

[13] The 2022 world health organization reevaluation of human and mammalian toxic equivalency factors for polychlorinated dioxins, dibenzofurans and biphenyls, Regulatory Toxicology and Pharmacology, Volume 146, January 2024, 105525.

Appendix B - Substance CAS Numbers and Hazard Statment Codes

Table B.1 below provides a summary of the CAS numbers and the associated hazard statment codes used for each substance identified[14] or assumed to be present[15] in this study. Hazard statment codes listed in the Great Britian Manditory Classification and Labelling (GB MCL) database must be used, and additional codes listed on the European Chemicals Agency (ECHA) have also been included where there are a significant number of notifiers.

Where a substance is not listed below, it was considered unclassified.

[14] Either through chemical screening or quantitative analysis

[15] Based on worst case metal compounds using semi-quantitative XRF scanning

Table B.1 CAS number and hazard statement used in study

	Substance	Acronym	CAS number	Hazard statement code
Metal compounds	Antimony trioxide		1309-64-4	H351
	Arsenic trioxide		1327-53-3	H350, H300, H314, H400, H410
	Lead compounds			H302, H332, H373, H400, H410, H360DF
	Zinc oxide		1314-13-2	H400, H410
Chlorinated paraffins	Medium-chain chlorinated paraffins	MCCP	85535-85-9	H362, H400, H410
	Short-chain chlorinated paraffins	SCCP	85535-84-8	H351, H400, H410
Organophosphate flame retardants	tricresyl phosphate/Tris(methylphenyl) phosphate	TCP	1330-78-5	H361, H400, H410
	Triphenyl phosphate	TPP	115-86-6	H400, H410
	Tris (1-chloro-2-propyl) phosphate	TCPP	13674-84-5	H302, H351, H412
	Tris(1,3-dichloro-2-propyl) phosphate	TDCIPP	13674-87-8	H351, H410
Brominated flame retardants	2,4,6-Tribromophenol	2,4,6-TBP	118-79-6	H302, H317, H319, H400, H410
	Hexabromocyclododecane	HBCD	25637-99-4	H361, H362
	Pentabromodiphenyl ether	Penta-BDE	32534-81-9	H362, H373, H400, H410
	Tetrabromobisphenol A	TBBPA	79-94-7	H350, H351, H400, H410
Phthalates	Benzyl butyl phthalate	BBP	85-68-7	H360Df, H400, H410
	Bis(2-ethylhexyl) phthalate	DEHP	117-81-7	H360FD, H400
	Dibutyl phthalate	DBP	84-74-2	H360Df, H410, H411
	Di-C7-11 alkylphthalates, branched and unbranched	DHUNP	68515-42-4	H360Df
	Diisobutyl phthalate	DIBP	84-69-5	H360Df, H410
	Di-isoheptyl phthalate	DIHP	71888-89-6	H360D
	Di-iso-octyl phthalate	DIOP	27554-26-3	H360FD
	Di-isopentyl phthalate	DIPP	605-50-5	H360FD, H400
	Di-n-pentyl phthalate	DPP	131-18-0	H360FD, H400
	n-pentyl-isopentyl phthalate	NPIPP	776297-69-9	H360FD, H400

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List of abbreviations

Abbreviation	Definition
C&D	Construction and demolition
Cl-OPFRs	Chloro-organophosphates
DCP	Dechlorane plus
Defra	Department for Environment Food and Rural Affairs
dl-PCBs	dioxin-like-polychlorinated biphenyls
EA	Environment Agency
EU	European Union
GC/MS	Gas chromatograph-mass spectrometry
HDCD	Hexabromocyclododecane
HWRC	Household waste recycling centre
LCCPs	Long chain chlorinated paraffins
LC-QTOFMS	high resolution mass spectrometry
MCCPs	Medium chain chlorinated paraffins
MRF	Materials recovery facilities
MSS	Marchwood Scientific Services
ndl-PCBs	non-dioxin-like-polychlorinated biphenyls
OPFRs	Organophosphate flame retardants
PCBs	Polychlorinated biphenyls
PBDE	Polybrominated diphenyl ethers

PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PFHxS	Perfluorohexanesulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
POPs	Persistent organic pollutants
SCCPs	Short chain chlorinated paraffins
TEFs	Toxicity Equivalency Factors
TEQ	Toxic Equivalent
UV-328	2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol
VU	Vrije Universiteit Amsterdam
WEEE	Waste Electrical and Electronic Equipment
EPS	Expanded polystyrene insulation
WTs	Waste transfer station
WFD	Waste Framework Directive
WRA	Wood Recyclers Association
XPS	Extruded polystyrene foam
XRF	X-Ray fluorescence

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