



# An assessment of the levels of Persistent Organic Pollutants (POPs) in Waste Electronic and Electrical Equipment in England & Wales

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## Summary report

Report prepared by Industry Council for Electronic Equipment Recycling (ICER) & Water Research Centre (WRC)

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## SUMMARY REPORT

### An Assessment of the levels of persistent organic pollutants in waste electronic and electrical equipment in England and Wales

#### i Need for study

Polybrominated diphenyl ethers (PBDEs) have been used extensively as flame retardants in the plastic components of electronic and electrical equipment (EEE). Certain PBDEs are listed in the Stockholm Convention on Persistent Organic Pollutants (POPs). POPs are organic chemical substances that persist in the environment, bioaccumulate through the food chain, and pose a risk of causing adverse effects to human health. TetraBDE, pentaBDE, hexaBDE and heptaBDE were listed as POPs in 2009 and decaBDE was added in 2017.

The EU POPs Regulation<sup>1</sup> implements the Stockholm convention and sets a maximum concentration limit (MCL) of 1,000 mg/kg for the total concentration of tetraBDE, pentaBDE, hexaBDE, heptaBDE and decaBDE in waste material. When items containing POPs above the MCL become waste they must be treated in such a way that the POPs are destroyed or irreversibly transformed.

There are also restrictions on POPs in products and materials placed on the market. The POPs Regulation<sup>1</sup> sets a cumulative MCL of 500 mg/kg for tetraBDE, pentaBDE, hexaBDE, heptaBDE and decaBDE. The RoHS Directive<sup>2</sup> banned PBDEs in electronic and electrical equipment (EEE) put on the market after 1<sup>st</sup> January 2007, though an exemption was made for decaBDE until July 2008. The REACH Regulation imposes additional controls on the marketing and use of PBDEs.

However, although the use of PBDEs in electrical and electronic equipment was banned from 2007/8, and many manufacturers had voluntarily phased them out before this, POPs may still

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<sup>1</sup> Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants.

<sup>2</sup> Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

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be present in waste electronic and electrical equipment (WEEE) arising today. This is partly because the lifespan of EEE is such that some products currently becoming waste were manufactured before the RoHS restrictions came into force. It may also be because recycled plastic containing POPs was used in their manufacture. Where POPs-PBDEs were used intentionally as flame retardants, levels of POPs could be as high 20 wt.% of the component, equivalent to 200,000 mg/kg. The levels of 'legacy POPs' resulting from use of recycled plastic are likely to be lower, but can still exceed the MCL.

In the UK there is a requirement for WEEE to be treated and recycled in accordance with The Waste Electrical and Electronic Equipment Regulations (2013) which implement the EU WEEE Directive<sup>3</sup>. If plastics in WEEE are contaminated with POPs they cannot be recycled and must be treated to destroy the POPs chemicals as required by the POPs Regulation<sup>1</sup>.

There is a need therefore to understand which categories of WEEE contain POPs-PBDEs, at what levels, and how these concentrations impact the management of WEEE and WEEE plastics.

## ii Method

The study analysed items from four of the UK's WEEE collection streams (large household appliances (LHA), small mixed WEEE (SMW), cooling and display) to establish whether they contained POPs or other substances of concern and at what level.

A substantial sampling programme was conducted at nine WEEE processing facilities in England and Wales and over 2,000 WEEE items were analysed using X-ray fluorescence (XRF) to provide chemical analysis of the plastic, in particular the bromine concentration. The data from this exercise gave insight into the proportion of plastic containing BFRs in different WEEE streams.

The XRF analysis allowed for targeted sub-sampling of WEEE items for further analysis. Samples of selected components, containing low, medium and high bromine concentrations, were sent for gas chromatography mass spectrometry (GCMS) analysis to identify the brominated compounds present in the plastic, with a particular emphasis on POPs-PBDEs.

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<sup>3</sup> Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)

### iii Findings

The study found POPs-PBDEs at concentrations above the MCL in components from several WEEE categories<sup>4</sup>.

The conclusions are set out below and summarised in Table S.1. The results of the study have been used to inform advice given by the Environment Agency regarding the classification of specific categories of WEEE.

#### Printed circuit boards (PCBs)

Significant concentrations of POPs-PBDEs were found in PCBs. Although none exceeded the MCL in the POPs Regulation, extraction efficiencies for brominated compounds from the PCB plastic matrix were shown to be low and therefore the concentrations determined by GCMS analysis are a considerable underestimate. Therefore, PCBs are likely to contain POPs-PBDEs above the MCL and should be treated as a POPs waste.

In a number of PCBs, the concentration of antimony, assumed to be present as antimony trioxide<sup>5</sup>, exceeds the MCL set out in the Classification, Labelling and Packaging (CLP) Regulation<sup>6</sup>. PCBs are therefore a hazardous waste.

#### Cables

POPs-PBDEs at levels above the MCL were found in some internal and external cables taken from various items of WEEE. The concentration of antimony, assumed to be present as antimony trioxide, was shown to exceed the MCL in a number of exterior and interior cables. WEEE cable is therefore both a POPs waste and a hazardous waste.

#### Cathode ray tube (CRT) displays

POPs-PBDEs at levels above the MCL were found in the plastic casings of some CRT displays and the concentration of antimony, assumed to be present as antimony trioxide, was shown to exceed the MCL in the CLP Regulation. CRT casings are therefore both a POPs waste and a hazardous waste.

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<sup>4</sup> The Waste Electrical and Electronic Equipment Regulations 2013.

<sup>5</sup> Antimony trioxide was commonly used alongside brominated flame retardants as a synergist and so all antimony detected via XRF is assumed to be present as antimony trioxide. The MCL for antimony trioxide is 1% (10,000 mg/kg) which equates to an antimony concentration of 0.84% (8,400 mg/kg).

<sup>6</sup> Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006.

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## Flat panel displays (FPDs)

POPs-PBDEs at levels above the MCL were found in the plastic casings of some FPDs. In a number of FPD casings, the concentration of antimony, assumed to be present as antimony trioxide, was shown to exceed the MCL in the CLP Regulation. FPDs are therefore both a POPs waste and a hazardous waste.

## Fridges

In this report, the term 'fridges' refers to fridges and freezers included in the category of Cooling Appliances Containing Refrigerants<sup>4</sup>.

The POPs-PBDEs concentrations in some small plastic components surrounding the fridge compressor were found to exceed the MCL in the POPs Regulation. However, when assessed as an entire unit, the total POPs-PBDEs concentration did not exceed the 1,000 mg/kg MCL. The plastic components surrounding the compressor should therefore be considered a POPs waste, but fridges as entire units are not a POPs waste. However, further work is required to assess the concentration of POPs-PBDEs and other hazardous substances in the waste plastic stream resulting from fridge treatment to inform future classification of this stream.

The concentration of antimony, assumed to be present as antimony trioxide, in some small components was shown to exceed the MCL in the CLP Regulation. These components are therefore hazardous waste. Fridges when assessed as entire units are classified as hazardous waste because of other substances they contain.

## Large domestic appliances (LDA)

In this report, LDA refers only to heavy white goods such as washing machines, tumble driers and dishwashers and not to the UK WEEE category large household appliances (LHA) nor to the LHA Collection Stream. Both the LHA category and collection stream include other items e.g. microwaves, radiators, fans as well as heavy white goods.

The POPs-PBDEs concentrations in some small plastic components of LDA were found to exceed the 1000 mg/kg in the POPs Regulation. However, when assessed as entire units, the total POPs-PBDEs concentrations in LDA items did not exceed the MCL. LDA items are therefore not a POPs waste when assessed as an entire unit. However, further work may be required to determine the concentration of POPs-PBDEs and other hazardous substances in the plastic fraction of LDA.

The concentration of antimony, assumed to be present as antimony trioxide, in some small components was shown to exceed the MCL in the CLP Regulation. However, when assessed as an entire unit of LDA, the antimony concentration did not exceed the MCL in the CLP



Regulation. Based on the information in this report therefore, LDA items are not a hazardous waste.

### Small mixed WEEE (SMW)

In this report, SMW refers to the collection stream intended for UK WEEE categories 2 to 10. POPs-PBDEs were found at levels exceeding MCL in the plastic components of several items. The size of the components relative to the weight of the whole items was such that the items exceeded the MCL of 1000mg/kg on an entire unit basis. The SMW collection stream is therefore a POPs waste stream.

SMW components were also found to contain antimony, assumed to be antimony trioxide, at concentrations exceeding the MCL. The SWM collection stream is a hazardous waste stream because of this and other substances it contains.

### Individual categories in SMW

UK WEEE Categories 2, 3, 6 and 7 (small household appliances; IT and telecoms equipment; electrical and electronic tools; toys, leisure and sports). Items from these categories were analysed as part of the SMW collection stream and found to contain POPs-PBDEs and antimony, assumed to be antimony trioxide, above the MCL. Therefore, these categories of SMW, if collected and treated separately, are both a POPs and a hazardous waste.

UK WEEE Category 1 (large household appliances). Items from this category were also analysed as part of the SMW collection stream and found to contain POPs-PBDEs and antimony above MCL. These were the smaller items from that category e.g. radiators, not large white goods e.g. washing machines. These smaller Category 1 items, if collected and treated separately, are therefore both POPs and hazardous waste.

UK WEEE Categories 4 and 5 (consumer equipment and lighting equipment). A number of items from these categories were analysed and found to contain bromine. Although the brominated compounds were not identified these categories are expected to contain POPs-PBDEs. Therefore, if collected and treated separately, these categories should be considered a POPs Waste in the absence of reliable supporting evidence to demonstrate that they are not. Both categories were found to contain concentrations of antimony above the MCL defined by the CLP Regulation and are therefore a hazardous waste.

UK WEEE Categories 8, 9 and 10 (medical devices; monitoring and control instruments; automatic dispensers). There is insufficient information from the study to comment on the POPs and antimony concentrations of these categories. The onus is therefore on the waste producer to classify them correctly.

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## Office equipment

### Dual use equipment disposed of by offices

Dual-use equipment disposed of by offices or businesses is similar to that disposed of by households in the SMW collection stream and the same classification considerations apply.

### Office equipment supplied as business to business equipment

This study has not obtained sufficient information to provide advice on the hazardous or POPs waste status of equipment which is supplied as business to business equipment, e.g. large printers, photocopiers.

Industry will need to undertake further work to determine if POPs or hazardous chemicals are present to ensure this waste is managed in an appropriate manner. In the absence of information a precautionary approach should be applied. It should not be assumed that waste is non-hazardous or not POPs waste without reliable supporting evidence.

### Detection of POPs

The study has shown that extraction efficiencies can be very low for some types of WEEE plastics, giving rise to a significant underestimate of POPs concentration. Analysis of POP-PBDEs in WEEE should measure extraction efficiency and highlight it in reported concentrations.

### WEEE European Waste Catalogue (EWC) codes

All wastes in the EU must be given an EWC code or list of waste (LoW) code as defined in the UK. This identifies the material as hazardous or non-hazardous and determines the treatment facilities to which it can be sent.

Based on the findings of this study, the Environment Agency is updating its existing guidance on classification to advise which EWC codes should be assigned to specific WEEE collection and material streams. Where two codes are issued this indicates that both should be assigned to the waste devices. The advice issued in September 2019 is outlined as follows. Additional advice is expected shortly.

- Display equipment (CRTs and FPDs as individual streams) – 20 01 35\* - *discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components.*
- Plastics removed from CRT display equipment (including those that are baled, shredded or crushed etc.) – 16 02 15\* - *hazardous components removed from discarded equipment* and 16 02 16 – *components removed from discarded equipment other than those mentioned in 16 02 15.*

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- Plastics removed from FPD display equipment (including those that are baled, shredded or crushed etc.) - 16 02 15\* - *hazardous components removed from discarded equipment* and 16 02 16 – *components removed from discarded equipment other than those mentioned in 16 02 15.*
  - Small mixed WEEE – 20 01 35\* - *discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components* and 20 01 36 - *discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 25.*
  - Treated small mixed WEEE – 19 02 04\* - *premixed wastes composed of at least one hazardous waste.*

The mixed output from treatment, e.g. shredding, of WEEE that includes hazardous waste or POPs waste remains a hazardous or POPs waste and must therefore be assigned the EWC code 19 02 04\*. However, if that shredded stream is sent for further mechanical treatment, e.g. a density separation process to separate the brominated fraction and the non-brominated plastics fractions, and if that process produces pure plastic output fractions, the EWC code 19 12 04 can be applied. This is a non-hazardous code and means that management options such as municipal waste incineration and use as alternative fuel in cement kilns are available for these plastic streams.



**Table S.1 Summary of classification of WEEE based on this study**

WEEE type	POPs waste	Hazardous waste
Printed circuit boards (PCBs)	✓	✓
Cables	✓	✓
Cathode ray tube displays (CRTs)	✓	✓
Flat panel displays (FPDs)	✓	✓
Fridges	X <sup>*</sup>	✓
Large domestic appliances (LDA)	X <sup>*</sup>	X <sup>*</sup>
Small mixed WEEE (SMW) as collection stream	✓	✓
Categories of SMW if collected separately	Cats 1, 2, 3, 6, 7 ✓ Cats 4,5 ✓ unless evidence provided to the contrary Cats 8,9,10 <sup>▲</sup>	Cats 1, 2, 3, 6, 7 ✓ Cats 4,5 ✓ unless evidence provided to the contrary Cats 8,9,10 <sup>▲</sup>
Office equipment	Dual use ✓ Business to business <sup>▲</sup>	Dual use ✓ Business to business <sup>▲</sup>

Further work required by industry to classify the plastic containing fractions produced by treating LDA and fridges.

<sup>▲</sup>The Environment Agency advises that industry needs to undertake assessment of these streams to determine correct classification status. In the absence of reliable evidence a precautionary approach should be adopted.

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## iv Further work

Further work is needed in the following areas:

- i) fridge plastic: to assess the POPs and hazardous content of the plastic stream arising from fridge treatment to ensure correct waste classification;
- ii) bromine separation of WEEE plastics: to characterise the light fraction from currently operating density separation processes to validate the ability of these processes to adequately separate potential POPs-containing plastics and provide a benchmark against which separation processes can be monitored and assessed;
- iii) printer Cartridges: to test for POPs and other hazardous substances;
- iv) alternative management options for POPs-containing plastic fraction: to establish feasibility of other advanced thermal treatment technologies for this material, such as gasification or pyrolysis;
- v) brominated compound extraction techniques: research to optimise and benchmark extraction techniques to avoid under reporting of data.

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## About us

Material Focus is a new not-for-profit organisation – our vision is of a world where materials are never wasted.

Three I's inform and guide everything we do: inspiration, investment and insight.

## Inspiration

We inspire people to change their behaviour. We do this through our Recycle Your Electricals campaign by revealing the hidden value of the materials in our electricals and by making it feel both easy (and normal) to reuse and recycle them.

## Investment

We work with partners to expand the number, and type of collection points, making it easier for everyone to reuse and recycle their old electricals.

## Insight

We fund technical research to overcome the barriers to reusing and recycling old electricals. Insight from this research galvanises new and innovative approaches to reuse and recycling, and supports enhancements to the UK waste electrical and electronic (WEEE) system.

