| | | |
|---|---|---|
| **Institution:** University of Birmingham | | |
| **Unit of Assessment:** 7 - Earth Systems and Environmental Sciences | | |
| **Title of case study:** Influencing policy and legislation on the use and disposal of chemical flame retardants | | |
| **Period when the underpinning research was undertaken:** 2004–December 2020 | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
| Professor Stuart Harrad | Professor of Environmental Chemistry | 1994–present |
| Dr Mohamed Abdallah | Lecturer in Persistent Organic Pollutants/Emerging Contaminants (previously postdoctoral research fellow and Doctoral Researcher) | 2016–present<br>2013–2016 (research fellow)<br>2006–2010 (doctoral researcher) |
| Dr Daniel Drage | Postdoctoral research fellow (previously doctoral researcher) | 2016–present (research fellow)<br>2009–2013 (doctoral researcher) |
| **Period when the claimed impact occurred:** January 2014 – Dec 2020 | | |
| **Is this case study continued from a case study submitted in 2014?** No | | |

## 1. Summary of the impact

Some flame-retardant chemicals in consumer items are harmful to humans, especially young children. Our **research evidence has led to policy and regulatory change** resulting in the **banning** of the use of *hexabromocyclododecane* (HBCDD) and *decabromodiphenyl ether* as flame retardants, as well as informing draft EU **regulation** of the use of chlorinated organophosphate flame retardants in polyurethane foam in children's products. We have also evaluated the use of low-cost methods to prevent materials containing banned flame retardants from going to landfill (with associated **environmental benefits**) or being recycled into children's toys. Taken together, these changes have demonstrable **health and wellbeing impacts** by reducing the exposure of vulnerable populations to harmful chemicals.

## 2. Underpinning research

To meet fire safety regulations, flame-retardant chemicals are added at 'per cent' levels to a wide range of consumer articles such as electrical and electronic equipment, as well as fabrics and foams used in furniture and vehicle interiors. Unfortunately, evidence has emerged that some of **these chemicals are harmful to humans and wildlife**. Our research has thus focused on quantifying the extent to which humans are exposed to these chemicals, to evaluate whether such exposure exceeds levels thought to be harmful. We have also **identified the pathways via which such exposure occurs so that public health guidance can be given on how to reduce exposure**. This is complex as exposure occurs via multiple pathways comprising the diet (including breast milk), inhalation of air (both indoors and out), ingestion of indoor dust, as well as dermal uptake via contact with flame-retarded items such as furniture fabrics. Another such pathway occurs when waste articles containing flame retardants are recycled, resulting in their unintended presence in new articles including plastic kitchen utensils and children's toys.

Against this backdrop, the specific key research findings (KF) underpinning the impact consist of 3 strands of activity:

**(KF1)** Since 2004, we have quantified human exposure via various pathways to brominated flame retardants (BFRs) including *hexabromocyclododecane* (HBCDD) and *decabromodiphenyl*

*ether*. **We have provided compelling evidence that substantial exposure of UK infants occurs via contact with indoor dust and breastfeeding** (R1, R2).

**(KF2)** Chlorinated organophosphate flame retardants (Cl-PFRs) are used very widely in polyurethane foam in mattresses, sofas, child car seats etc. Between 2013–2018, Harrad and Abdallah quantified **absorption through the skin by children of Cl-PFRs** and demonstrated that uptake through the skin exceeded substantially levels thought hitherto (R3, R4).

**(KF3)** The EC has set legislative limits on maximum levels of BFRs in waste articles. Such limits are designed to prevent discarded materials containing such BFRs being recycled (and thus inadvertently contaminating new goods like children's toys containing recycled material with BFRs). However, the vast number of waste articles requiring compliance testing renders existing laboratory methods economically unfeasible with each test using existing methods costing ~£300. Using portable X-ray fluorescence (XRF), Harrad, Abdallah, and Drage have developed a **rapid, user-friendly, and affordable (~£2/test) approach for measuring bromine in waste articles containing BFRs** (R5, R6).

## 3. References to the research

**R1**: S. Harrad, C. Ibarra, M. A. Abdallah, R. Boon, H. Neels, A. Covaci, "Concentrations of brominated flame retardants in dust from United Kingdom cars, homes, and offices: Causes of variability and implications for human exposure", *Environment International*, 34: 1170–1175 (2008). DOI: 10.1016/j.envint.2008.05.001

**R2**: M. Abdallah, S. Harrad, "Polybrominated diphenyl ethers in UK human milk: Implications for infant exposure and relationship to external exposure" *Environment International*, 63: 130**–**136 (2014). DOI: 10.1016/j.envint.2013.11.009

**R3**: M. A-E. Abdallah, G. Pawar, S. Harrad, "Human dermal absorption of chlorinated organophosphate flame retardants; implications for human exposure", *Toxicology and Applied Pharmacology*, 291: 28–37 (2016). DOI: 10.1016/j.taap.2015.12.004

**R4**: M. A-E. Abdallah, S. Harrad, "Dermal contact with furniture fabrics is a significant pathway of human exposure to brominated flame retardants", *Environment International,* 118: 26–33 (2018). DOI: 10.1016/j.envint.2018.05.027

**R5**: M. Sharkey, M. A-E. Abdallah, D. S. Drage, S. Harrad, H. Berresheim, "Portable X-ray fluorescence for the detection of POP-BFRs in waste plastics", *Science of the Total Environment*, 639: 49–57 (2018). DOI: 10.1016/j.scitotenv.2018.05.132

**R6**: D. S. Drage, M. Sharkey, M. A-E. Abdallah, H. Berresheim, S. Harrad "Brominated flame retardants in Irish waste polymers: Concentrations, legislative compliance, and treatment options", *Science of The Total Environment*, 625: 1535–1543 (2018). DOI: 10.1016/j.scitotenv.2018.01.076

## Research Grants

Research Grant Award to Harrad by Environmental Protection Agency of Ireland. "Screening of the Irish Waste Stream for Persistent Organic Chemicals (SAFER)". Grant reference 2018-RE-LS-3. Amount awarded €468,131 (€282,240 to University of Birmingham). Duration 2/2019–2/2022.

Research Grant Award to Harrad by Environmental Protection Agency of Ireland. "Elucidating Levels and Pathways of Human Exposure in Ireland to POP-BFRs and PFOS (ELEVATE)". Research Grant reference 2015-HW-MS-4. Amount awarded €335,564 (€202,799 to University of Birmingham). Duration 3/2016–9/2019.

Research Grant Award to Harrad by Environmental Protection Agency of Ireland. "Identification and Treatment Options for Waste Streams of Certain Bromine Containing Flame Retardants (WAFER)". Grant Reference 2014-RE-MS-2. Amount awarded €348,834 (€252,337 to University of Birmingham). Duration 2/2015–7/2017.

Research Grant Award to Harrad by European Commission. "Elucidating Sources & Pathways of Environmental Contamination with Brominated Persistent Organic Chemicals Using Advanced Instrumental Tools (ELUTE)". Marie Curie European Industrial Doctorate Network co-ordinated by

Harrad. Grant Reference 606857. Amount awarded €1,174,267. Duration 10/2013–10/2017.

Research Grant Award to Harrad by European Commission. "Assessment of dermal absorption of organic flame retardant chemicals using 3D in vitro human skin models (ADAPT)." Marie Curie Individual Fellowship Award to Mohamed Abdallah. Grant Reference 327232. Amount awarded €221,406. Duration 7/2013–7/2015.

Research Grant Award to Harrad by European Commission. "Advanced Tools for Exposure Assessment and Biomonitoring (A-TEAM)". Marie Curie Initial Training Network co-ordinated by Harrad. Grant Reference 316665. Amount awarded €4,246,567 (€968,246 to University of Birmingham). Duration 1/2013–1/2017.

Research Grant Award to Harrad by European Commission. "Indoor Contamination with Flame Retardant Chemicals: Causes and Impacts (INFLAME)". Marie Curie Initial Training Network co-ordinated by Harrad. Grant Reference 264600. Amount awarded = €3,631,363 (€749,360 to University of Birmingham). Duration 1/2011–1/2015.

## 4. Details of the impact

This impact is focussed upon the **protection of human health and the environment by reducing exposure to flame retardants**. This is achieved by:

1. Assisting in the banning of harmful brominated flame retardants (BFRs) highlighted to pose a specific risk to breastfeeding infants;
2. Influencing new draft regulations governing use of chlorinated organophosphate flame retardants (Cl-PFRs) in children's products;
3. The development of innovative technology to maximise the recycling of plastics whilst minimising the risk of harmful chemicals being used in new products (e.g. toys).

Cumulatively, these changes are improving **health and wellbeing** by reducing the exposure of children and other vulnerable populations to harmful chemicals linked to adverse impacts on the liver, thyroid and reproductive/developmental, neurological, and immunological systems.

Improved public health and wellbeing via reductions in exposure to brominated flame retardants

By assisting the work of the Review Committee of the United Nations Environment Programme Stockholm Convention on Persistent Organic Pollutants (POPs), KF1 and KF2 have led to a **ban of the manufacture, and new use, of two extensively used brominated flame retardants** (BFR). As a result of this research, two new chemicals were listed as POPs under the convention, namely *hexabromocyclododecane* (HBCDD) in 2013 [S1] and *decabromodiphenyl ether* in 2017 [S2]. Being listed as a POP has international implications, as the 152 signatories to the Stockholm Convention (including the UK, the EU, and China), become committed to the ban. This has led to notable reductions in human exposure over the impact period, particularly for HBCDD.

Since the banning of HBCDD, **cessation of production** has since happened in Europe, Japan, and the US, with the 2018 risk assessment of HBCDD by the US Environmental Protection Agency noting "environmental exposures are expected to decline […] for this persistent and bioaccumulative compound" [S3]. Indeed, evidence has started to emerge of **improved health and wellbeing** as a significant decline in HBCDD concentrations in human milk in Ireland, demonstrating the reduced exposure of nursing infants and mothers [S4]. The importance of this pathway has also been acknowledged by the UK Committee on Toxicity (COT) in a series of evidence statements **providing advice to government departments and agencies** [S5a, b, c, d]. The chair of COT testified:

> Prof Harrad's research constitutes the only source of information on the exposure of the UK population to PBDEs [polybrominated diphenyl ethers] and HBCDDs via ingestion of dust and breast milk. It was thus crucial in informing the COT's conclusions that there existed possible concerns regarding the exposure of infants to HBCDDs, BDE-99 and -209 via ingestion of dust, and to BDE-47, -99 and -153 via breast milk. […] without Prof. Harrad's research it would not have been possible for the COT to assess the risks from exposure of

> infants and young children to these compounds and that this will help inform in [sic] the Government's dietary recommendations for infants and young children. [S6]

Decisions by regulatory authorities to control the use of Cl-PFRs have been influenced by the research

Human exposure to flame retardants **highlighted a new issue of concern which is now informing changes in European regulation**. Recommendations based on KF2 demonstrating substantial dermal exposure to Cl-PFRs used in flexible polyurethane foam in childcare articles has played a **pivotal role in the draft recommendation** [S7] of the European Chemicals Agency (ECHA) regarding Cl-PFRs. This will result in an EU-wide ban on the use of the chemicals in polyurethane foam in children's mattresses, nursing pillows, and child car seats (impacting ~29 million children across Europe aged under five currently exposed to such articles). The draft recommendation (citing R3) notes:

> [previous EU risk assessments] did not specifically assess dermal exposure of children. [For infants…]. dermal exposure appears […] the main route of exposure [...] Other routes or sources of exposure are negligible in comparison. [S7]

Impacts on the environment by the improved detection of plastics containing banned BFRs

Whilst increasing regulation of flame retardants will reduce human exposure to harmful chemicals, a danger still persists where old goods are recycled into new products such as children's toys. To prevent contamination, the EC sets limit values for the use of BFR-containing waste but mass screening has previously proved economically unfeasible. University of Birmingham research [KF3] has **influenced new methods that are leading to environmental benefits** in the waste and recycling industry, meaning that more waste consumer goods are recycled, rather than landfilled, incinerated, or exported. As testified by a Scientific Advisor for the Irish Government, Harrad's research [KF3] has provided:

> the most comprehensive evaluation to date of hand-held X-ray fluorescence (XRF) as a means of measuring whether BFR concentrations exceed EC limits. It has demonstrated that this approach can successfully identify waste articles that exceed the EC limit values and is a viable means of **enforcing the EC's legislative limits**. [S8]

A further benefit of the approach is that the profitability of the **recycling industry will also be impacted by the introduction of the new method**. Axion Recycling in the UK estimate that the improved identification of plastics which comply with EC regulations and are thus recyclable, will generate annual economic activity of £8.4m and create 100 jobs over five years [S9].

**5. Sources to corroborate the impact**

**S1:** Stockholm Convention on Persistent Organic Pollutants, HEXABROMOCYCLODODECANE - DRAFT RISK PROFILE (Draft prepared by the ad hoc working group on hexabromocyclododecane under the POPs Review Committee of the Stockholm Convention, UNEP/POPS/POPRC.6/10). Paragraphs 31, 76, 78, 79, and 103 document specific contributions from the Harrad group.

**S2:** Risk profile document for decabromodiphenyl ether produced by UNEP's Stockholm Convention Persistent Organic Pollutants Review Committee (25 November 2014) (Report of the Persistent Organic Pollutants Review Committee on the work of its tenth meeting: Risk profile on decabromodiphenyl ether (commercial mixture, c decaBDE) UNEP/POPS/POPRC.10/10/Add.2) that has led to the chemical's listing as a POP under the Stockholm Convention. (This source contains citations to 7 publications by Harrad and Abdallah)

**S3:** USEPA (United States Environmental Protection Agency) 2018. Problem Formulation for Cyclic Aliphatic Bromides Cluster (HBCD). EPA Document# EPA-740-R1-7012 (this source contains citations to 11 publications by Harrad)

**S4:** Wemken, N., Drage, D. S., Cellarius, C., Cleere, K., Morrison, J. J., Daly, S., Abdallah, M. A-E., Tlustos, C., Harrad, S., Coggins, M. A., "Emerging and legacy brominated flame retardants in the breast milk of first time Irish mothers suggest positive response to restrictions on use of HBCDD and Penta- and Octa-BDE formulations", *Environmental Research*, 180: 108805 (2020). https://doi.org/10.1016/j.envres.2019.108805

**S5a:** UK COT statement on the potential risks from polybrominated diphenyl ethers (PBDEs) in the infant diet (March 2015). (This source contains 5 citations to work by Harrad, including R1 and R2).

**S5b:** UK COT Statement on the potential risks from hexabromocyclododecanes (HBCDDs) in the infant diet (April 2015). (This source contains 9 citations to work by Harrad)

**S5c:** Addendum to the 2015 COT Statement on potential risks from hexabromocyclododecanes (HBCDDs) in the infant diet (October 2016). (This source contains 3 citations to work by Harrad)

**S5d:** Addendum to the 2015 COT statement on potential risks from polybrominated diphenyl ethers (PBDEs) in the infant diet: potential risks from polybrominated diphenyl ethers (PBDEs) in the diets of infants and young children (November 2017). (This source contains 3 citations to work by Harrad)

**S6:** Testimonial from the chair of the UK COT (Prof. Alan Boobis) corroborating the impact of our research on the COT's risk assessment of PBDEs and HBCDD. [Dated 31 January 2020]

**S7:** European Chemicals Agency (ECHA). Draft Screening Report – An Assessment of Whether the Use of TCEP, TDCP, and TDCP in Articles Should be Restricted, Version 3, 5 April 2018. (R3 is cited in this report at page 55. It is the only study cited that provides data on uptake across the skin of these chemicals)

**S8:** Testimonial from Dr Darren Byrne (Technical/Scientific Advisor within the Irish Government's Environmental Advisory Unit) corroborating the impact of our research on Irish national policy on monitoring compliance with EC limits on BFRs in waste. [Dated 7 February 2020]

**S9:** Testimonial from Axion. [Dated 8 December 2020]