Institution: University of Birmingham

Unit of Assessment: UOA 7 – Earth Systems and Environmental Sciences

Title of case study: Indoor contamination: Impact on international environmental regulatory policy on the flame retardant chemical Hexabromocyclododecane (HBCD)

1. Summary of the impact

In May 2013 the UN Environment Programme's Stockholm Convention on Persistent Organic Pollutants agreed to ban the widely-used flame retardant Hexabromocyclododecane (HBCD), following evidence that there may be harmful human exposure. Since the Convention came into force in 2004, only 21 compounds have had their use either banned or tightly restricted under its terms. **Research findings from Stuart Harrad and his group at the University of Birmingham formed a significant element of the case used to support the ban on HBCD**. Harrad's group provided the first measurements made anywhere in the world on concentrations of individual HBCD isomers in indoor dust leading to the realisation that the ingestion of indoor dust was a significant pathway of human exposure to HBCD. The group has also contributed important evidence of the capacity of HBCD to bioaccumulate and of its environmental persistence.

2. Underpinning research

The underpinning research for this impact was led by Harrad as part of the work of the Environmental Health Sciences Group within the School of Geography, Earth and Environmental Sciences at the University of Birmingham and began in 2006.

Harrad's team have carried out research which has assessed human exposure to a series of persistent organic pollutants (POPs). A particularly novel feature is the team's focus on the role of indoor contamination in driving this exposure. The team have also exploited the chiral properties of POPs to provide new insights into their sources, environmental fate and behaviour.

One strand of this research has been the environmental fate and behaviour of hexabromocyclododecane (HBCD), which is a flame retardant found in domestic environments through its use in building insulation, textile coatings and plastics used in the computer industry. Particular attention has been on the aquatic bioaccumulation of HBCD and the magnitude and pathways of human exposure. Central to this work has been the development and application of robust, state-of-the-art hyphenated chromatographic/mass spectrometric techniques to monitor concentrations of the various HBCD isomers in a range of environmental matrices.

The overarching aim of the research was to develop understanding of the environmental occurrence and fate of HBCD from its myriad sources in indoor environments through the outdoor environment and ultimately into biota and humans. The data produced were designed to inform evaluation of the environmental and human health risks of HBCD. The research provided the first measurements made anywhere in the world on concentrations of individual HBCD isomers in indoor dust (1,2) leading to the realisation that the ingestion of indoor dust was an important pathway of human exposure to HBCD. Moreover, exposure of young children under some scenarios was shown to exceed that of occupationally-exposed adults working in factories handling HBCD (1). The research also generated the first data on contamination of school classrooms with HBCD and related brominated flame retardants (3). Combined, these studies played an important role in highlighting the elevated exposure received by young children. Moreover, the statistically significant correlation between HBCDs in dust from individuals' homes and in their blood (4) and mathematical modelling of the external contributors to UK body burdens (5) emphasised the importance of this pathway for adults also. Harrad's group also provided the first data worldwide on freshwater contamination by HBCD and field measurements of bioaccumulation factors for a number of freshwater fish (6).

The research has been conducted through a PhD studentship provided by the Egyptian government and via a grant from the Big Lottery Fund under the Open Air Laboratories (OPAL) project. Additional support was provided via an Exploratory Workshop funded by the European Science Foundation. Ongoing work in this area continues with funding from several sources thereby demonstrating the widespread interest from stakeholders in this topic, including studentships funded by the NERC, the EU, and the China Scholarship Council, with additional support from AEA Technology plc, the Centre for Environment, Fisheries, and Aquaculture Sciences, and the Food Standards Agency.

Names of key researchers at Birmingham and position held by those researchers at the time of the research: Professor Stuart Harrad (Reader at time of research; Dr. Mohamed Abdallah (Doctoral Researcher 8/06-2/10); Dr. Jennifer Desborough (Doctoral Researcher 10/07-3/11); Mrs. Congqiao Yang (Doctoral Researcher 11/10-present); Ms. Cassandra Rauert (Doctoral Researcher 5/11-present); Mr. William Stubbings (Doctoral Researcher (10/11-present)).

3. References to the research

(1) Abdallah MA, Harrad S, Ibarra C, Diamond M, Melymuk L, Robson M, Covaci A. Hexabromocyclododecanes in indoor dust from Canada, the United Kingdom, and the United States. *Environmental Science and Technology*, 42, 459-464 (2008). DOI: 10.1021/es702378t

(2) Abdallah MA, Harrad S, Covaci A. Hexabromocyclododecanes and tetrabromobisphenol- A in indoor air and dust in Birmingham, U.K: implications for human exposure. *Environmental Science and Technology*, 42, 6855-6861 (2008). DOI: 10.1021/es801110a

(3) **Harrad S, Goosey E, Desborough J, Abdallah MA, Roosens L, Covaci A. Dust from U.K. primary school classrooms and daycare centers: the significance of dust as a pathway of exposure of young U.K. children to brominated flame retardants and polychlorinated biphenyls. *Environmental Science and Technology*, 44, 4198-4202 (2010). DOI: 10.1021/es100750s**

(4) **Roosens L, Abdallah MA, Harrad S, Neels H, Covaci A. Exposure to hexabromocyclododecanes (HBCDs) via dust ingestion, but not diet, correlates with concentrations in human serum: preliminary results. *Environmental Health Perspectives*, 117, 1707-1712 (2009). DOI: 10.1289/ehp.0900869**

(5) Abdallah M. Harrad S. Tetrabromobisphenol-A, Hexabromocyclododecane and Its Degradation Products in UK Human Milk: Relationship to External Exposure. *Environment International*, 37, 443–448 (2011). DOI: 10.1016/j.envint.2010.11.008

(6) **Harrad S., Abdallah MA, Rose NL, Turner SD, Davidson TA. Current-Use Brominated Flame Retardants in Water, Sediment, and Fish from English Lakes. *Environmental Science and Technology*, 43, 9077–9083 (2009). DOI: 10.1021/es101746s**

References 3, 4 and 6 best demonstrate the quality of the underpinning research.

4. Details of the impact

There have been growing concerns about the pollutant effects of HBCD and in May 2013 the UN Environment Programme's Stockholm Convention on Persistent Organic Pollutants (POP) agreed to a ban on its use which will come into force in 2014. At present more than 22,000 tons of HBCD are used globally, with production taking place in the USA, Europe and Asia (source 1, para 21).

The research findings from Harrad's group were significant sources of evidence used in the risk profile for HBCD drawn up for the Convention's POPs Review Committee and made a distinct and material contribution to the Convention's decision. Harrad's expertise on HBCD was also utilised in a report commissioned by Defra to consider the UK's stance when regulation was under consideration by the Convention.

Global regulation of HBCD

The UN Environment Programme's Stockholm Convention on Persistent Organic Pollutants has

179 parties (178 states and the EU), as at May 2013. Since the Convention came into force in 2004, only 21 compounds have had their use either banned or tightly restricted.

In June 2008, Norway initiated a proposal to add HBCD to this list of globally-regulated compounds. In order to be listed as a POP under the Convention, there must be evidence of: (1) potential for long-range transboundary atmospheric transport, (2) adverse effects, (3) persistence, and (4) bioaccumulation.

The Convention's POP Review Committee (POPRC) considered a draft risk profile on HBCD at its meeting in October 2010, which said that "Based on the available evidence, it is concluded that HBCD is likely, as a result of long-range environmental transport, to lead to significant adverse environmental and / or human health effects, such that global action is warranted." (source 1, Executive Summary, para 7). Subsequently, at its October 2011 meeting, the Committee recommended that HBCD be listed under the Convention, with this confirmed at a further meeting on 19th October 2012.

As a consequence, the Conference of the Parties (the Convention's governing body) at their 6th meeting held from 28th April to 10th May 2013 in Geneva, agreed to list HBCD under Annex A of the Convention. This means that the production and use of HBCD will be banned from 2014, with some exceptions to 2018 for its use in building insulation (source 2).

Role of Birmingham research

Harrad's findings contributed to this process by providing information on the magnitude and pathways of human exposure to HBCD that contributed to the assessment of potential adverse human health effects. His substantial body of research has driven the conclusion that dust is one of the main sources of exposure (source 1, paras 6 and 31, and section 2.3.2), with six of his papers cited in the risk profile.

Of particular value were Harrad's studies which revealed that children ingest more HBCD than adults. One of the authors of the risk profile, [redacted] of Fisheries and Oceans Canada, has written to the University to confirm that "*Dr Harrad's studies showed, unequivocally, that children ingest more HBCD through this exposure route than adults and has raised concerns that this could contribute to developmental and neurotoxic effects in infants*". [redacted] highlighted Harrad's findings during his plenary talk to the POP Review Committee in 2009 and introduced the committee to the idea that as an exposure route dust (as well as diet) accounted for a significant portion of the exposure to humans, especially infants (source 3).

The initial proposal to ban HBCD was made by the Norwegian Royal Ministry of the Environment, and further confirmation of the role played by the Birmingham research has been provided by [redacted], Chief Scientist of the Norwegian Institute of Public Health. As well as attesting to the contribution Harrad's work had made to knowledge concerning human exposure, Professor Becher confirmed the important role played by this research in establishing the persistence and bioaccumulative capacity of HBCD:

"Doubts were raised by industry and others whether HBCD was persistent as standardised biodegradation tests in soil and sediments did not meet the half-life screening criteria of the Convention. This would also mean that the extent of exposure to HBCD for biota and humans and the resulting risks would be low.

Both [redacted] and experts from Environment Canada then evaluated the latest research results on HBCD with the aim to demonstrate that HBCD fulfils all the criteria of the Convention. In

this respect, the research of Stuart Harrad and his group was extremely valuable. They demonstrated clearly the abundance of HBCDs in abiotic samples of sediments and the bioaccumulative property of HBCD in fresh water fish providing evidence of persistence and potential for human exposure via fish consumption.

Further, Harrad's group has provided evidence for the occurrence of HBCD in dust from various indoor environments resulting from its use in building insulation, textile coatings and plastics used in electronic equipment. Through their work, it was recognised that ingestion of dust can be an important source of human exposure besides food. They produced evidence that particularly young children with their characteristic hand-to-mouth behaviour are at risk for elevated exposures. These new exposure scenarios made a significant contribution to the elucidation of human exposure to HBCD and possible health impacts for the risk profile on HBCD adopted by the POPs Review Committee in 2010. Based, among others, on this document, the Committee has proposed for the Conference of the Parties to list HBCD under the Stockholm Convention on POPs" (source 4).

Impact on UK policy and practice

In the UK, Defra has paid close attention to the implications of international regulation of HBCD. In 2010, the Department commissioned AEA Technology to investigate this. AEA's report (source 5) estimated that approximately 1000 tonnes of HBCD are used per year in the UK, of this around 90% was used in the construction industry, with the balance used in the textiles and electronics industries (source 5 p.3).The report informed Defra's negotiating stance in relation to the proposed listing of HBCD under the Stockholm Convention.

Harrad contributed expertise on the environmental chemistry of HBCD for the AEA report (source 5 section 1.5, page 11), and his findings on the degradation, aquatic bioaccumulation, and human exposure to HBCD, contributed substantially to the report's conclusions. The main conclusion of the report was that, whilst damage to human health has not been demonstrated unambiguously, there is clear evidence for human exposure, and HBCDs meet the Stockholm criteria for persistence and bioaccumulation and, hence, for international regulation.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. 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.
2. "Nations agree to phase out toxic chemical HBCD", AFP 10th May 2013.
3. Letter from Research Scientist and Adjunct Professor, Fisheries and Oceans Canada, Winnipeg, MB, dated 18th July 2012.
4. Letter from Chief Scientist, Norwegian Institute of Public Health dated 18th July 2012.
5. AEA Technology, *Costs and Benefits of the Addition of Hexabromocyclododecane (HBCD) to the Stockholm Convention and the 1998 POPs Protocol* (Report for Department for Environment, Food and Rural Affairs, Restricted Commercial, ED56226, Issue Number 5, Date 12 October 2010). Harrad acted as technical expert on this report.
6. Letter from Principal Consultant, AEA Technology, 4th July 2012.
7. Letter from officer responsible for relationships between air pollutants and ecosystems, Atmosphere and Local Environment Programme, Defra, dated 23rd November 2012.