United States Environmental Protection Agency

FLAME RETARDANT ALTERNATIVES FOR HEXABROMOCYCLODODECANE (HBCD)

Chapter 1

Introduction

FINAL REPORT

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1 Introduction

1.1 Background

As part of its effort to enhance the safety of chemicals, the U.S. Environmental Protection Agency (EPA) has taken steps to identify chemicals that may pose environmental and health concerns. Between 2009 and 2011, EPA developed action plans that considered both potential regulatory and voluntary actions. In August 2010, EPA released the Hexabromocyclododecane (HBCD) Action Plan[1]. This Action Plan summarized hazard, exposure, and use information to help evaluate the environmental and health risks associated with HBCD[2].

HBCD is a brominated flame retardant found worldwide in the environment and wildlife. Human exposure is evidenced from its presence in breast milk, adipose tissue, and blood. It bioaccumulates and biomagnifies in the food chain. It persists and is transported long distances in the environment, and is highly toxic to aquatic organisms. HBCD also presents potential human health concerns based on animal test results indicating potential reproductive, developmental, and neurological effects.

HBCD is a flame retardant most commonly used in expanded polystyrene foam (EPS) and extruded polystyrene foam (XPS). EPS and XPS are used as insulation in the building and construction industry. HBCD is also used in materials such as textile back coatings on institutional carpet tiles or upholstery and some military fabrics (U.S. EPA 2012). A minor use of HBCD is in high-impact polystyrene (HIPS) for electrical and electronic applications such as audio-visual equipment, refrigerator linings, and in wire and cable (U.S. EPA 2010).

The Action Plan stated EPA's intent to conduct this Design for the Environment (DfE) Program alternatives assessment: *Flame Retardant Alternatives for Hexabromocyclododecane (HBCD).* DfE's Alternatives Assessment Program helps industries choose safer chemicals and provides a basis for informed decision-making by developing an in-depth comparison of potential human health and environmental impacts of chemical alternatives. DfE convened a multi-stakeholder partnership to help select and evaluate flame retardant alternatives to HBCD and develop this report. Partnership representatives from industrial, academic, governmental, and non-governmental organizations (NGOs) engaged with DfE to provide input from a variety of different viewpoints. The chemical alternatives chosen for this report were included because they were identified by stakeholders as potential functional alternatives. Including these alternatives does not indicate that EPA considers them to be preferable in terms of environmental or health hazard, or any other metric. This report did not evaluate efficacy of these alternatives which may be related to specific material and product applications and related standards. Stakeholders provided professional judgment about whether chemicals are likely to meet flammability tests in

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[1] The Hexabromocyclododecane (HBCD) Action Plan is available online at: http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/hbcd.html.

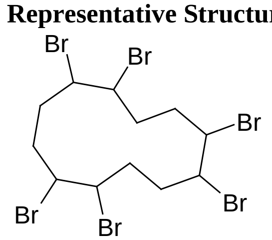
[2] HBCD should not be confused with hexachloro-1,3-butadiene (HCBD). For information about HCBD, see http://www.epa.gov/opptintr/chemtest/pubs/hexchbut.html.

EPS and XPS. The report does provide information that will enable more informed selection of alternative flame retardants to HBCD for EPS and XPS.

Several international governmental entities have begun to take actions towards regulating HBCD in recent years, including the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP) (United Nations Economic Commission for Europe 2011), the Stockholm Convention on Persistent Organic Pollutants (POPs) (Stockholm Convention on Persistent Organic Pollutants 2008), the European Union (European Chemicals Agency 2011), Canada (Environment Canada 2010), and Australia (Australian Department of Health and Aging: National Industrial Chemicals Notification and Assessment 2008). In the United States, the HBCD Action Plan proposed several regulatory actions to manage the risk that may be presented by HBCD (U.S. EPA 2010). As the regulation of HBCD is considered in the U.S. and internationally, this alternatives assessment will be an important resource both in reporting on the environmental and human health profiles of HBCD alternatives and in helping product manufacturers select safer alternative flame retardants. The information will help reduce the potential for the unintended consequences that could result if functional but poorly understood or more hazardous alternatives are chosen as chemical substitutes to HBCD.

HBCD is a category of brominated flame retardants, consisting of 16 possible isomers. It has a molecular formula (MF) of $C_{12}H_{18}Br_6$ and its structure consists of a ring of 12 carbon atoms to which 18 hydrogen and six bromine atoms are bound. HBCD may be designated as a non-specific mixture of all isomers (Hexabromocyclododecane; CASRN: 25637-99-4) or as a mixture of three main diastereomers (1,2,5,6,9,10-hexabromocyclododecane; CASRN: 3194-55-6). Both mixtures are listed on the Toxic Substances Control Act (TSCA) Inventory and have substantial use in U.S. commerce (10-50 million pounds in 2005). A representative structure of HBCD is shown in Figure 1-1 below.

Figure 1-1. Representative Structure of HBCD



HBCD is an effective flame retardant for building insulation materials and does not compromise the physical properties of the foam. HBCD is uniquely suited for use in EPS and XPS foam due to its effectiveness at low concentration levels, compatibility with current manufacturing processes and chemicals, and low water solubility. Alternatives to HBCD must meet the same functional requirements; there are currently few viable[3] alternatives to HBCD for EPS or XPS.

[3] Viability refers to the functional performance of a chemical as a flame retardant in EPS and XPS foam, not the environmental preferability of the chemical nor other product performance criteria.

Alternatives to HBCD have been discussed previously in reports published by the European Commission and the University of Massachusetts at Lowell (Morose 2006; IOM Consulting 2009). These assessments looked at alternatives to HBCD for its uses in building insulation, textile back coatings, and HIPS applications, and identified flame retardant alternatives as well as alternative forms of insulation to the use of HBCD in building insulation. This EPA report provides new and updated information on chemical flame retardant alternatives to HBCD in its primary use as a flame retardant for insulation foam.

1.2 Purpose of the Flame Retardant Alternatives Assessment

The purposes of this assessment are to: (1) identify viable alternatives for HBCD in EPS and XPS; (2) evaluate the human health and environmental profiles of HBCD and its alternatives; and (3) inform decision making as organizations choose safer alternatives to HBCD. Within DfE Alternatives Assessments, chemicals are not ranked for preferability, rather the information provided is intended for use by decision-makers, who will combine our assessment with other information to inform the selection of safer, more sustainable alternatives.

1.3 Scope of the Flame Retardant Alternatives Assessment

The Action Plan issued for HBCD in 2010 called for EPA to conduct a DfE multi-stakeholder alternatives assessment to aid users in selecting safer alternatives to HBCD.

Since the primary use for HBCD is for EPS and XPS foam insulation, the project scope did not include alternatives to HBCD for its minor uses in textile back coatings and HIPS used in electronics housings and focused on primary uses. Stakeholders interested in alternatives for these uses may refer to DfE's Partnership on Alternatives to Decabromodiphenyl Ether (decaBDE).[4] The decaBDE report considers alternative flame retardants for a wider range of polymers and applications, including electronics housings and textiles, for which both decaBDE and HBCD have been used in the past.

The assessment provides hazard information (human toxicity, ecotoxicity, environmental fate) on flame retardants that were selected for evaluation in this report as potentially viable alternatives to HBCD. Viable alternatives are those that may have similar performance and function to HBCD when used in EPS and XPS building insulation. While the assessment will not attempt to include comprehensive life-cycle assessment (LCA) information, it will, by both inclusion and reference, note relevant life-cycle considerations, describe other relevant information, and provide a general overview of potential alternative materials that may aid in the selection of alternatives to insulation containing HBCD. An in-depth comparison of potential human health and environmental impacts was not done for the alternative insulation materials described in Section 5.2. The information provided by this Partnership will help stakeholders select preferable alternatives to HBCD; however, the report will not recommend specific flame retardants or alternative materials.

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[4] http://www.epa.gov/dfe/pubs/projects/decaBDE/index.htm

The report is organized as follows:

- **Chapter 1** *(Introduction)*: This chapter provides background on the Flame Retardant Alternatives to HBCD project, including the purpose and scope of the Partnership and of this report.

- **Chapter 2** *(HBCD Uses, End-of-Life, and Exposure)*: This chapter describes the insulation products in which HBCD is used and the potential associated exposure pathways along each stage of the life cycle of the flame retardant in the products.

- **Chapter 3** *(Background on Flame Retardants)*: This chapter describes chemical flame retardants generally, as well as those specific to this assessment and provides technical information about flammability standards.

- **Chapter 4** *(Hazard Evaluation of HBCD and Alternatives)*: This chapter explains the chemical assessment method used in this report and summarizes the assessment of hazards associated with each flame retardant chemical.

- **Chapter 5** *(Summary of Hazard Assessments, Considerations for Selecting Flame Retardants and an Overview of Alternative Materials)*: This chapter includes a summary of the human health, environmental, social, performance, and cost considerations for selecting alternative flame retardants. It also includes an overview of information on alternative insulation materials, although the Partnership does not provide a direct comparison of these materials to EPS and XPS foam.

1.4 DfE Alternatives Assessments as a Risk Management Tool

Among other actions, the Agency chose to conduct a DfE Alternatives Assessment as a risk management tool for HBCD in EPA's HBCD Action Plan. The Agency chose this tool to inform the chemical substitution that may occur as an outcome of other activities described in the Action Plan. DfE Alternatives Assessments provide information on the environmental and human health profiles of chemicals that may be used as substitutes so that industry and other stakeholders can use this information, in combination with analysis of cost, performance, and other factors, to make informed choices about alternatives.

DfE Alternatives Assessments along with LCAs, risk assessments, and other tools can be used to improve the sustainability profiles of chemicals and products. These tools, which can be complementary, should be selected according to the risk management need. DfE Alternatives Assessments establish a foundation that other tools can build on.

The focus of this DfE Alternatives Assessment report is to compare the intrinsic properties of chemicals within the same functional use group (e.g., *solvent, surfactant, flame retardant, ink developer*) and to evaluate alternatives across a consistent and comprehensive set of hazard endpoints. Information about chemical hazards derived from this type of comparative chemical hazard assessment can be used by decision-makers to help them select safer alternative chemicals.

Risk assessment and DfE Alternatives Assessment are both based on the premise that risk is a function of hazard and exposure. Risk assessment characterizes the nature and magnitude of hazard and exposure from chemical contaminants and other stressors.

DfE's "functional use" approach to alternatives assessment orients chemical evaluations within a given product type and functionality. Under this approach, factors related to *exposure scenarios*, such as physical form and route of exposure, are generally constant within a given functional use analysis and would fall out of the comparison. DfE Alternatives Assessments consider intrinsic properties of chemical substitutes that affect *exposure potential*, including absorption, persistence, and bioaccumulation. Under this approach, the health and environmental profiles in the alternatives assessments become the key variables and sources of distinguishing characteristics. Exposure attributes, including significant differences in environmental fate and transport based on persistence, bioaccumulation, and physical properties, are considered and discussed in Chapters 4 and 5.

DfE Alternatives Assessments are most useful in identifying safer substitutes when available alternatives meet performance requirements and are expected to present lower hazards for human health and the environment. During decision-making, risk assessment or LCA could be applied to the lower-hazard or potentially preferable alternatives to complement the alternatives assessment findings. Alternatives assessments can also identify the characteristics of a safer alternative and guide innovation and product development, especially when clearly preferable alternatives are not available.

The DfE Alternatives Assessment approach is aligned with green chemistry principles.[5] The relationship to two of those principles is especially noteworthy:

- Principle 4: *Designing Safer Chemicals* -- "Design chemical products to affect their desired function while minimizing their toxicity," and
- Principle 10: *Design for Degradation* -- "Design chemical products so they break down into innocuous products that do not persist in the environment."

DfE incorporates these two green chemistry principles and applies them in its assessment of chemical hazard and fate in the environment. This approach enables identification of safer substitutes that emphasize greener chemistry and points the way to innovation in safer chemical design where hazard becomes a part of a performance evaluation.

[5] http://www.epa.gov/sciencematters/june2011/principles.htm

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