EXPOSURE OF HBCD AND ITS ALTERNATIVE FLAME RETARDANTS BASED ON SUBSTANCE FLOW ANALYSIS

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Introduction

The development of safer alternatives to problematic chemicals and products have attracted increasing attention[1]. A variety of methodological frameworks for the alternatives development have been established. In the current chemical assessment, however, the risk from alternative chemicals has been rarely considered, because little information is available on their environmental impacts. As a result, it is uncertain whether poorly understood or potentially more hazardous new alternative chemicals may be applied. For the comprehensive chemical risk management, an integrated methodology which includes the approach, not for only the evaluation of target chemical risk but for potential impact substituting the target chemical with alternatives has been needed. The present study aims to contribute to developing a multi risk reduction policy for brominated flame retardants and its potential alternative flame retardants.

In this study, we focused on hexabromocyclododecane (HBCD), a brominated flame retardant used in polystyrene insulation board and textile fibers. Its use has been debated in many countries on account of its potential risks to wildlife and human health, and whether it should be phased out as a persistent organic pollutant. Several potential HBCD alternatives have been proposed in Japan although their assessment does not still contribute to the decesion for environmental preferability. In our previous study, we estimated quantitative life-cycle flow and environmental emission of HBCD and its alternative flame retardants for the two scenarios (i.e., continuous use of HBCD and the replacement to HBCD alternatives by the cessation of the use of HBCD)[2]. Here, we estimate exposure of HBCD and its potential alternative flame retardants based on quantitative substance flow. Our objectives were to evaluate the exposure of alternative flame retardants by the cessation of the use of HBCD

Materials and methods

To estimate the exposure for HBCD and its alternative flame retardants, we assumed two scenarios. Scenario 1 is the continuous use of HBCD without any ban of HBCD and scenario 2 is the replacement to its alternatives for each application, due to the ban on the use of HBCD. Details have described elsewhere[2]. We focused on HBCD alternatives in three applications (i.e., XPS and EPS as polystyrene insulating boards and interior textiles). These

Table1 physicochemical property of HBCD and its potential alternative flame retardants estimated by EPI suite

		HBCD	TBNP*	TBCO*	BCA*
Application			XPS	EPS	Textile
Molecular weight		641.7	1018.5	427.8	728.7
Water solubility	(mg/L)	2.1E-05	3.3E-08	6.9E-02	7.5E-01
Vapor pressure	(mmHg at 25°C)	1.7E-08	2.1E-08	7.1E-05	1.3E-07
Melting point	(°C)	180.03	90.27	102.18	87.23
Boiling point	(°C)	462.03	480	342.77	448.73
Kow	Log10	7.74	8.05	5.24	3.59

potential alternatives were selected from the interview with relevant company. But our assumption may not reflect the real situation in Japan so far.

The exposure amount was calculated based on multimedia fate model and food-chain exposure model. In a calculation of environmental concentrations, we used a Mackay-type Ⅲ multimedia fate model. For physicochemical property of HBCD and its alternatives, the data were estimated by using EPI suite. Table 1 list the input parameter in this study. Geographic parameters were used for the value in Japan. For the food-chain exposure model, we considered the following routes: food intake, drinking water consumption, soil ingestion, and inhalation. The route of food intake was included in fish, meat and milk, vegetables and root.

Results and discussion

We analyzed exposure of HBCD and its potential alternative flame retardants from 1986 to 2020. The predicted exposure of HBCD and its alternatives for two scenarios are shown in Figure. 1. For the scenario of HBCD continuous use (scenario 1), HBCD was increased over the entire time period in this study. The fish was the largest contributor of HBCD exposure (90%), followed by those from consumer products. Previous study, which was calculated the exposure via dust and diet, has reported that food intake is the most important contributor to total intake (mean, 67%; range, 23-97%), although the value were varied depending on dust intake scenario[3].

In the case of replacement to HBCD alternatives by the cessation of the use of HBCD (scenario 2), the estimated HBCD exposure decreased from 2009, which was the start period of replacing to its alternatives. For the comparison of exposure over time between scenario 1 and scenario 2, HBCD in scenario 2 decreased following by the cessation of its use after 2008 and finally decreased 17 % in 2020 compared to the continuous HBCD use scenario. This result suggests that the abandon of HBCD use would be effective for the decrease of HBCD exposure. On the other hand, small but a significant estimated exposure would continue since 2014, which is the finish period of the replacement to alternatives. The contribution from consumer product accounted for approximately 20% of total exposure in 2020, whereas it accounted for approximately 10% in 2010. HBCD in products remain for decades. HBCD emission from product may continue to some extent for decades, in spite of the replacement to its alternatives. These results indicated that products containing HBCD would be a potential source of exposure for a long time.

For the alternative flame retardants of HBCD, estimated exposure increased continuously from1986 to 2020 in scenario2 (Fig.1(c)-(e)). The contribution from drinking water (mean, 2%) for alternative of textile and from root for alternative of EPS (mean, 15%) were observed although the fish was the largest contributor for all alternatives exposure.

The use of combination of a multimedia fate model and food-chain exposure model based on substance flow model which is considered for the replacement to its potential alternatives, allowed us to compare possible exposure between target chemicals and its alternative. On the other hand, Areas of uncertainty and variability remain in the emission factors. In particular, the emission factor from waste stage (i.e., landfill and incineration) has not been included in this study. Our study clearly highlights the need for improved understanding and measurement of the emission factors for HBCD and for accurate flows in post-consumer use. So far, there have

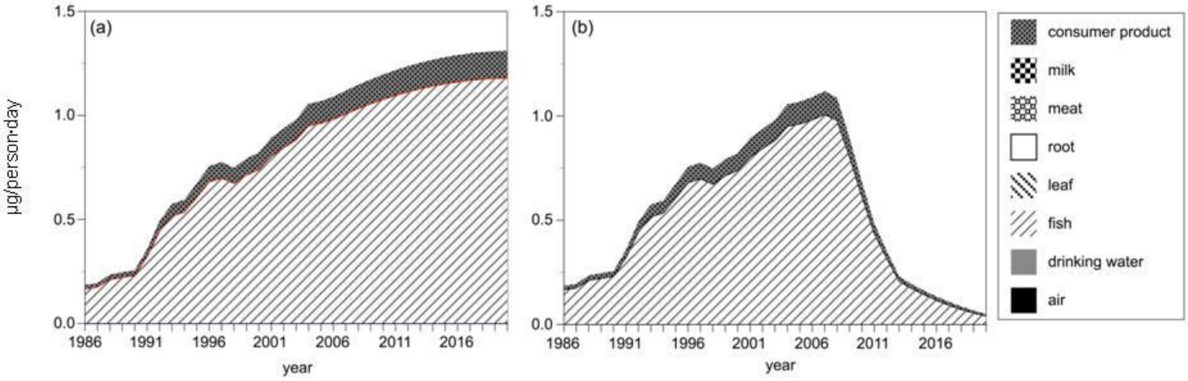

Figure 1 Exposure of HBCD and its alternatives in Japan

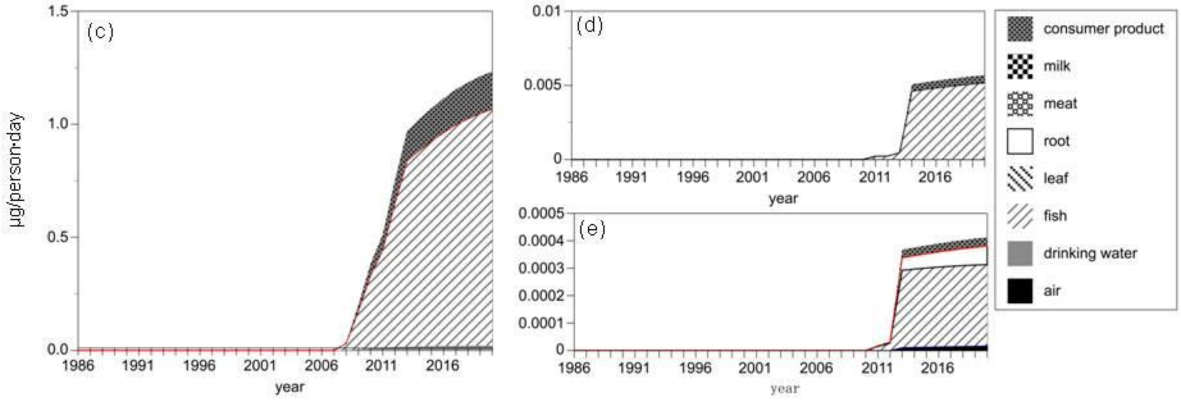

Figure 1 Continued: (a) exposure of HBCD in the continuous use scenario, (b) exposure of HBCD in the scenario of replacement to its alternatives, (c) exposure of alternative for textile in the scenario of replacement to its alternatives, (d) exposure of alternative for XPS in the scenario of replacement to its alternatives and (e) exposure of alternative for EPS in the scenario of replacement to its alternatives

been only limited data on the emission inventories from the waste stream into the environment compartment. Further study should focus on the potential for releases from the waste stream. Current research also focused on the comparison of life cycle exposure health risk between HBCD and its alternatives.

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Acronyms and abbreviations
TPNP : Tris[3-bromo-2,2-bis(bromomethyl)propan-1-yl]phosphate
TBCO : tetrabromooctane
BCA: 10-benzil-9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide