P-258 Evaluation of the Risk Trade-off Concerning Brominated Flame Retardants in EU – Phase Out of Deca-BDE and Increase of TV Fires –

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Abstract

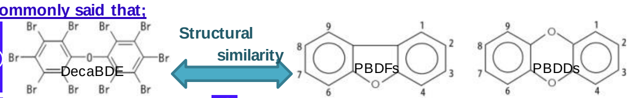
Overview: We focused on Decabromodiphenyl ether (DecaBDE), which is known as cost-effective brominated flame retardant used in TV enclosure components, for the evaluation of risk trade-off caused by the avoidance of its use. ***Background:*** Risk trade-off framework, which enables to evaluate and compare the different type of risks, such as human health risk and fire risk is constructed. To date, several governments, especially in EU, made clear that their approach against environmental issue is based on the precautionary principle. Thus, there observed a tendency to place more value on human health risk than physical risk (i.e. fire risk in this case). ***Strategy:*** In the current study, we tried to quantify and compare these risks. ***Result (1):*** At first, we conducted a Cost Benefit Analysis (CBA) considering human health impacts of DecaBDE use and both economic and health damage by TV fires. The results suggested that net benefits of DecaBDE use were positive under all the five scenarios considered. ***Result (2)***: Secondly, we tried to re-evaluate the net benefits of DecaBDE use by replacing the rate of TV fires with more stringent one. Although it diminished fire rate by 75%, under the most realistic two scenarios, results showed positive net benefits of DecaBDE use.

1. Introduction

Application of DecaBDE:

In Late 90's, *Albemarle Corp.* declared that 85% of DecaBDE is used in HIPS for casings of EE appliances [1].

It is commonly said that;

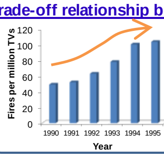
① 

② Debromination to lower PBDEs ③ Diffuse into Environment and accumulated in biota

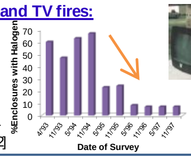
Human health effects of DecaBDE:

European Chemicals Bureau (ECB) concluded that there were at present no need for further information and/or testing, and no need for risk reduction measures beyond those which had been taken already to protect both human health and the environment.

Trade-off relationship between DecaBDE use and TV fires:



← **Fig.1** Trends in number of TV fires in Sweden [2]



← **Fig.2** TV set enclosures tested that contained halogens [3]

2. Goal of this quantitative Cost Benefit Analysis

We tried to answer the following questions;

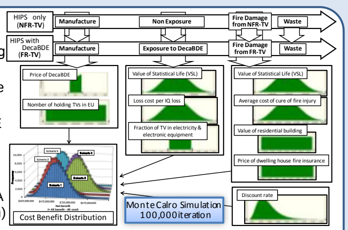
Do the benefits, which obtained as reducing number of TV fires, overweigh the human health risks caused by exposure to DecaBDE, and how much the margin of benefits are there?

3. Method

(is based on the CBA by Simonson[4])

We improved Simonson's CBA concerning about following points;

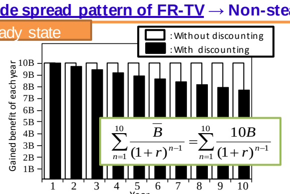
1) Assuming the costs and benefits as non-steady state
2) Excluding the cost for deposition of TV
3) Taking adverse effects to human health of DecaBDE used in TV enclosure components into account
4) Taking uncertainties of several parameters into account, using Monte Carlo Simulation



→**Fig. 3** Schematic of DecaBDE CBA (Only the parameters with distribution are shown)

1) Wide spread pattern of FR-TV → Non-steady state

Steady state

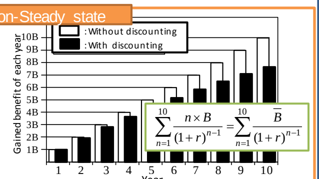


$$\sum_{n=1}^{10}\frac{\bar{B}}{(1+r)^{n-1}}=\sum_{n=1}^{10}\frac{10B}{(1+r)^{n-1}}$$

Fig. 4 Conceptual diagram for gained annual benefits (steady state, present value)

$$\therefore \bar{B}=10B \quad (1)$$

Non-Steady state



$$\sum_{n=1}^{10}\frac{n\times B}{(1+r)^{n-1}}=\sum_{n=1}^{10}\frac{\bar{B}}{(1+r)^{n-1}}$$

Fig. 5 Conceptual diagram of gained annual benefits (non-steady state, present value)

$$\therefore \bar{B}=\frac{r}{(1+r)-(1+r)^{-9}}\sum_{n=1}^{10}\frac{n\times B}{(1+r)^{n-1}} \quad (2)$$

($\bar{B}$: gained annual benefits at present (practically in later 90's) when 10% FR-TV of all possessed TV have been replaced in EU (US$/year); B : gained annual benefits (US$/year); r : discount rate; n: year)

Simonson's CBA

$$\bar{B}=\sum_{n=1}^{10}\frac{B}{(1+r)^{n-1}} \quad (3)$$

Finally, We chose **formula (2) (non-steady state)**, because
1) for the estimation of worst case scenario
2) for realistic consideration, such as gradual phase-out of DecaBDE in HIPS in EU

2) Estimation of human health risks caused by DecaBDE use

Human health impact model in **Washington state** → Extrapolation → **EU**

Excess lifetime cancer risk $=4.5\times10^{-4}$

$$Effect_{EU} = Effect_{WA}\times\frac{Deca_{E\&E}}{Deca_{All}}\times\frac{Deca_{TV}}{Deca_{E\&E}}\times\frac{TV_{EU}}{TV_{WA}} \quad (4)$$

Table 1 Extrapolating the human health risks estimated in Washington state model into EU

	Lifetime health impact	Case number	Unit value	Time conversion index	Converted value (2005 price)
Parameters in Washington-model[5]	Annual Cancer	5	$US\$_{2004}$ 26,976	1.034	US$139,466
	Annual Cancer Mortality	4	$US\$_{1990}$ 4,800,000	1.495	US$28,704,000
	Annual Hypothyroid Case Entering Treatment	2,400	$US\$_{2004}$ 7,940	1.034	US$19,703,904
	Annual Subclinical Hypothyroid Pregnancies	30	$US\$_{2004}$ 7,940	1.034	US$246,299
	Annual IQ impacts	210	$US\$_{2000}$ 14,500	1.134	US$3,453,030
	Delay to replace electronics [-][5]				0.87
	Delay to disorder timing [-][5]				0.91
Extrapolating Washington to EU	$Deca_{E\&E}/Deca_{All}$	Range: 0.8~0.9, uniform distribution derived from Lassen *et al.*[6]			
	$Deca_{TV}/Deca_{E\&E}$	Range: 0.97~0.98, uniform distribution derived from Lassen *et al.*[6]			
	TV_{WA}	Median: 26.8 million TV, Range: ±10%, uniform distribution (to reflect on sensitivity analysis.)			
	TV_{EU}	Median: 230 million TV [4], Range: ±10%, uniform distribution (to reflect on sensitivity analysis.)			
	Annual costs in EU by loss of human health (median value)				$US\$_{2005}$ 25,726,392

4. Results and Discussion

Table 2 Scenarios for our CBA calculations

Scenario	Discount rate	Human health risk	House fire
1	No	Yes	No
2	Yes	Yes	No
3	Yes	No	Yes
4	Yes	Yes	Yes
5	Yes	Yes	Indirectly (Insurance)

1) Monte Carlo Simulation (100,000 iterations)

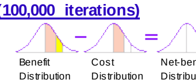


Table 3 Parameters for calculation, and their distributions for Monte Carlo Simulation

Parameter	Value used in this analysis
Cost of DecaBDE [4][7][8]	Min: US$0/TV, Max: US$3.30/TV, Maximum likelihood value: US$3.30/TV, Triangle distribution [US$2.00/TV, US$3.30/TV]
Value of Statistical Life (VSL) [9]	Av: $US\$_{2005}$7.2 on, SD: $US\$_{2005}$4.84 on, Weibull distribution, type 3
Social costs of DecaBDE's health impact	cf. Table 1
Average cost for treatment of fire victims [4][10]	Median: US$180,000, 90%tile: US$225,000, Normal distribution
Discounting rate [11]	5%tile:3%, 95%tile:10%, Lognormal distribution
TV life-cycle	10 year
Number of deaths avoided per year [4]	160 persons/year
Number of injuries avoided per year [4]	2,000 persons/year
Number of full fire-damaged houses avoided [4]	11 / TV/year
Average cost of restoring full-damaged house [4]	Median: US$ 180,000, Range: ±10%, Uniform distribution (to reflect on sensitivity analysis.)
Number of TV fires avoided (including housing fire) [4]	107 / TV/year
Average cost per fire [4] (Based on statistics from the Swedish Fire Insurance Federation)	Median: US$ 7,500, Range: ±10% Uniform distribution (to reflect on sensitivity analysis.)

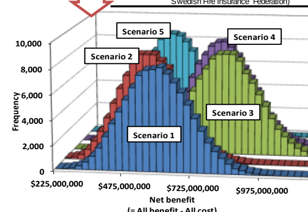


Fig. 6 Distribution of annual net benefits (before VSL was re-evaluated)

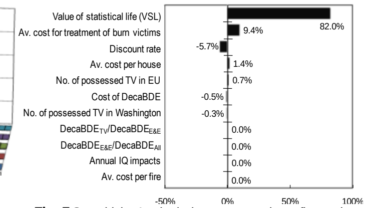


Fig. 7 Sensitivity Analysis between net benefits and parameters (Fig. 6, scenario 4)

Fig. 6 suggested that;

①The benefits gained by adding inflammability overweighed its costs (= risk) even when human health impacts were included.

②It was strongly suggested that human health risks were too small to be ignored (comparing the Scenario 3 and 4)

③One parameter, which was average cost per housing, affected the result considerably (comparing the Scenario 3, 4 and other scenarios).

2) Re-evaluate VSL (Value of Statistical Life) as realistic value

Table 4 List of official VSLs in several EU countries

Country	Official VSL of every country	VSL($US\$_{2005}$)
United Kingdom	$£_{1997}$ 1.00~1.60 million $£_{1998}$ 1.05 million	1.60~2.56 million 1.94 million
Sweden	SEK_{1997} 14.3 million	1.56 million
Finland	FIM_{1999} 11.26 million	1.98 million
Germany	$¥_{2004}$ 177 million	1.20 million
Netherlands	$¥_{2004}$ 296 million	2.02 million

Av.: $US\$_{2005}$1.77 million
SD: $US\$_{2005}$0.38 million

By adopting lognormal distribution

Official value of VSL in EU

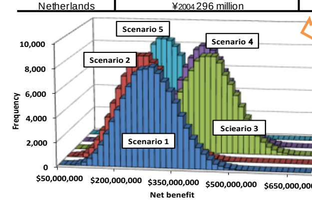


Fig. 8 Distribution of annual net benefits (after VSL was re-evaluated)

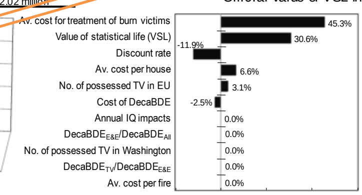


Fig. 9 Sensitivity Analysis between net benefits and parameters (Fig. 8, scenario 4)

①**Fig. 9** represents that the sensitivity of VSL clearly decreased while sensitivity of other parameters increased.

②The results shown in **Fig. 8** suggested that all the scenarios assumed distribution was reconstructed with relatively narrow ranges, and the median shifted to lower net benefit.

③Human health impacts affected net benefits only by 0.36% increase.

3) Re-evaluation of TV fire using more stringent data

Table 5 Data of fire damage rate (Unit person/year/million TV)

	Deaths avoided	Injuries avoided
Simonson	0.696	8.70
Clarke [12]	0.415	5.18
Muir [13]	0.200 (0.087-0.387)	2.50 (1.05-4.77)

Scenario 1, 2, 5 (unrealistic scenario):

There is a possibility that the net benefits were negative (respectively 15%, 10%, 2%).

Scenario 3, 4 (realistic scenario):

It was impossible for the net benefits of Scenario 3 and 4 to be negative.

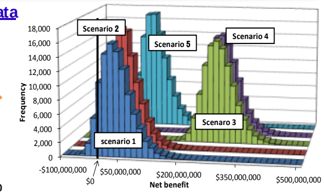


Fig. 10 Distribution of annual net benefits by using Muir's estimation of TV fire's data

It is summarized as follows:

Although we decreased TV fire rate by 75% (Muir's estimation), the results even showed positive net benefits of DecaBDE use at the very least under the most realistic scenarios.

References [1] Leisewitz A., Kruse H., Schramm E., Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals Resultsand Summary Overview. 2001. [2] Stiftung Warentest, 4 (1993) p. 23; 11 (1993) p.29; 5 (1994) p.35; 11 (1994) p.39; 5 (1995) p.24; 11 (1995) p.30; 5 (1996) p.28; 11 (1996) p. 30; 5 (1997) p.47; 11 (1997) p.28. [3] De Poortere M.,Schonbach C.,Simonson, M. *Fire and Materials* 2000; 24: 53. [4] Simonson M., Andersson P., van den Berg M. SP report 2006:28. 2006. [5] Washington State Departments of Ecology and Health, Washington State PBDE Chemical Action Plan: Final Plan. 2006. [6] Lassen C., Havelund S., Leisewits A., Maxson P., Deca-BDE and Alternatives in Electrical and Electronic Equipment. Danish EPA. 2006. [7] Stevens G.C., Mann A.H., DTI Report: URN98/1026. 1999. [8] Pure Strategies, Inc., Decabromodiphenylether. An Investigation of Non-Halogen Substitutes in Electronic Enclosure and Textile Applications.2005. [9] U.S. EPA, The Benefits and Costs of the Clean Air Act 1990 to 2010, EPA Report Congress. 1999. [10] RPA,*Risk Reduction Strategy and Analysis of Advantages* and *Drawbacks for OctaBDE*, Final Report. 2002. [11] MIC Japan, Committee for Policy Assessment of Regulatory, Final Report. 2007. [12]Muir, T. *Organohalogen compounds* 2007; 69: 2611. [13] Clarke F., The life safety benefits of brominated flame retardants in the United States. Final Report to the Chemical Manufacturers Association Brominated Flame Retardant Industry Panel. Benjamin/Clarke Associates 1997.