COSTS AND BENEFITS OF BROMINATED FLAME RETARDANTS (BFRs) AND ALTERNATIVES

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Introduction

The brominated flame-retardants are one of many substances used to reduce inherent fire hazards in a variety of commercial applications, such as electronics, plastics, furniture, and textiles. In many cases the use of some kind of flame retardant is required by regulation and statute, however, there are numerous non-halogenated flame retardants in use (BFRs comprise only about 25% of the total volume on a global scale), and other practices and potential polymer technologies exist that can reduce the risks of fire.[1,2,3] As a result of the inherent physico-chemical properties of BFRs - highly lipophilic, persistent, and bio-accumulative - structural similarities to compounds known to be toxic, such as PCBs, PBBs, PCDDs and PCDFs, a limited amount of data on certain BFR toxicities, and large and growing anthropogenic production and use volumes, these compounds have become known as a novel group of global environmental contaminants.[1,4,5,6,7,8] Trends in environmental presence of a particular subgroup of BFRs, the polybrominated diphenyl ethers (PBDEs), especially in human mother's milk, have been referred to as "alarming".[9] Such trends have resulted in reductions in use in Sweden, and a recent European Union decision to ban the use of the Octa- and Penta-BDE formulations as of July 1, 2003.[10] In light of these actions, and the inherent physico-chemical potential of the BFRs and their metabolites and degradation products to be toxic, particularly as developmental neurotoxicants, [2,4,5,6,8] the aim of this paper is to provide an analysis of some of the economic and health costs and benefits that are and maybe associated with the use of the BFRs, including PBDEs, compared to possible non-halogenated alternatives in a North American context.

Methods and Materials

The methods used involve the examination of several lines of evidence, including empirical, toxicological, methodological, and theoretical. Selected literature was reviewed to determine the basis of the expressed concern and actions. Then, standard economic principles and methods were applied to published data on potential costs and benefits associated with the BFRs, and PBDEs in particular, as compared to non-halogenated alternatives.

Results and Discussion

The noting of an increasing trend in the levels of PBDEs in biota and humans, and indications that this increase may be rapid, has become of increasing concern to scientists over the last decade. While our knowledge of the toxicity of these compounds is limited, what information is available indicates that the toxicological endpoints of concern for environmental levels of PBDEs are similar to those seen earlier for PCBs, and are likely to be thyroid hormone disruption, neurodevelopmental deficits, and cancer.[2,4,5,6,8]

While current environmental levels may still offer a margin of safety for the mean exposure to PBDE from food, the increasing concentration in human mother's milk was and is driving the alarm and concern. In North America, the limited data on concentrations of PBDEs in human mother's milk show a rapidly rising trend from 0.2 ng/g in 1982 , to 202.2 ng/g in 2000.[10] A first-order kinetic growth curve for the 4 points indicates a doubling time of 2 years. The latest concentration can be compared to the maternal milk PCB concentrations reported by Jacobson and Jacobson[11] as being associated with a 6.2 point loss in full-scale IQ scores and strong effects related to memory and attention in the most highly exposed group (1.25 µg/g or greater), and poorer word comprehension and overall reading comprehension and several other intellectual deficits, in the two groups with highest exposure (1.00 µg/g or greater). These concentrations were only slightly higher than those in the general population.

These exposure concentrations are only about 5 and 6 times higher than the year 2000 PBDEs concentration for North America. If we use a doubling time of 2 years, based on the above data for North America, then in 6 years time the PBDE concentrations in human mother's milk in North America will be greater than 1.6 µg/g and exceed the highest exposure category in the Jacobson's sample. A doubling time of 5 years achieves this result in about 12 years. There were 30 children or 14 % of the sample in this group, and 66 children or 31 % in the two highest exposure groups. Note that there is no NOEL for neurodevelopmental effects established for PBDEs.[4]

In a previous study,[12] we reported that the loss of earnings for a 1 point IQ loss, measured for the 6 years of age cohort of children in the United States, was from $55 billion to about $65 billion per year. For the 14 % of the Jacobson's sample that experienced the 6.2 point loss this equates to from $7.7 billion to $9.1 billion per IQ point, or a total of $47.7 billion to $56.4 billion for the 6.2 point loss. It was also estimated that selected social costs associated with a 3 point loss in population IQ totaled more than $19 billion for the U.S.. Proportioning this by the 14 % yields another $2.7 billion, and if it is doubled to reflect the 6.2 point loss, this yields $5.4 billion. There are other economic costs reflective of lost economic growth and development potential due to lost intellectual capacity (low estimate $17.1 billion per year of which 31 % equals $5.3 billion), and the costs of special education, and general treatment of the learning, developmental and behavioral disabilities that accompany the deficits measured by the Jacobson's, and that in actual fact affect nearly 12 million children in the U.S.. These last costs are estimated at from $81.5 billion to $167 billion per year, which for the 31 % of the Jacobson cohort showing discernible effects on intellectual capacity, amounts to about $25 billion to almost $52 billion per year. Overall, these costs, which are by no means a complete estimate, total $83.4 billion to $119.1 billion per year, calculated for the Jacobson results.

There are also indications that adults, and especially women, are experiencing thyroid disease, especially hypothyroidism, which appears to be endemic in North America.[4,12] In turn, this maternal hypothyroidism is one mechanism by which the fetus and neonate are affected, and which leads to the kind of health outcome seen by the Jacobson's, and that is reported in other related literature. While beyond the present study, these outcomes and their health and economic costs need to be considered.

In comparison to the costs identified above, which the evidence suggests might be the outcome of a failure to control and reduce the releases of BFRs, and PBDEs in particular (recall the lack of a NOEL noted above), we can consider what the benefits of these flame retardant compounds might be. While BFRs of all kinds are used to reduce the hazards and risks of fire, there are a wide variety of alternatives, the majority by volume being non-halogenated and inorganic.[1] Given these alternatives, it is important to understand two basic principles of benefits assessment. First, the benefits of a material in use cannot be meaningfully discussed without specifying the alternative materials that could be used, or can be developed or improved and used. The second principle, related to the first, is that the "benefit" of a material in use is the net amount in comparison to the alternative. To be truly beneficial a material must have a positive net benefit in this comparison.

While it is reported that flame retardants save human lives, and that BFRs have certain commercial advantages, there is no evidence that alternatives could not provide the same protection to life.[3] It is reported that the use of alternatives may require higher loadings, be more expensive, and may affect the properties of the polymer(s), however, in large measure this is a technical problem that is not insolvable. As well, use of high thermal stability polymers that do not need FR additions, and the application of nanocomposites technology in FR, are expected over the medium term.[7] Thus, based on our principles above, there is no evidential basis for attributing saved human lives solely to the use of BFRs, and therefore, no basis for attributing this as a benefit to their use exclusively.

However, for purposes of illustration and discussion, we can put that lack of evidence aside. Even using the unsupported report that BFRs saved 2,600 lives in the U.S. in 1994[3] and assuming that these lives could not be saved by alternatives, and using a U.S. EPA estimate of the value of a statistical life of $2 million to $5 million,[13] yields a dollar benefit of $5.2 billion to $13 billion a year assuming the same rate of life-saving over time. However, because the causality of fire deaths involves probability distributions and not individual events, it is likely, but perhaps not certain, that most if not all of these lives would be saved by the use of alternatives. Assuming a 95 % confidence in this would leave a 5 % residual chance of statistical lives being lost in cases using alternatives. This would yield an expected dollar benefit to BFRs of $260 million to $650 million a year.

To compare the health and economic cost estimates provided above with these uncertainty estimates of the saved-lives benefits of BFRs, we can use another uncertainty analysis. For example, if the probability of PBDEs alone reaching the levels in the environment projected above were the same 5 % used in the benefits estimate above, this would yield an expected value of the health and economic costs presented above of $4,200 million to $6,000 million per year. If this same probability were just 1 %, these costs would be $834 million to $1,200 million per year. Both of these estimates of costs are significantly in excess of the estimates of benefits. Indeed, for the expected value of the costs (unreduced total) and benefits (residual of 5 % of lives saved) to be equal, the probability of the PBDEs alone reaching the concentrations estimated and having the effects and costs noted (with no additional interactions with other BFRs or compounds) would have to be from 1 chance in 321 to 1 chance in 183.

The potential for extra costs associated with the use of alternatives can also be considered. If there are cost advantages of the BFRs over alternatives that may be substituted, this would be a benefit of the BFRs. It is reported that worldwide use of BFRs was about 682 million pounds a year, with a value of 1,100 million Euro., or about $880 million U.S. This works out to $1.29 a pound. Of this annual worldwide use, 148 million pounds is PBDEs. The use in the U.S. and the Americas totals 129 million pounds for all BFRs and 18.3 million pounds for the penta-BDE.[4,7]

In a study done for Canada of alternatives to chlorinated FRs,[14] it was found that the cost of the aluminum trihydrate (ATH), and phosphorus compounds, including loading increases of 3, and 1/3, respectively, was 3/8, and 2 times, respectively. Assuming the high cost estimate of twice as much, this would involve a cost of $166 million for all BFRs and $23.6 million for just the Penta-BDEs, for switching in the Americas. As a proportion of the value of end-use polymer, plastics, foams, textiles, and electronics, these cost increases are vanishingly small. These substitution costs, which are an estimate of the price-based benefits of BFRs over alternatives, are three orders of magnitude less than the total identified potential economic and health costs discussed above. Compared to a 5% chance of the health impacts happening, these price benefits, which are the only ones that are supported by evidence, are still essentially two orders of magnitude less.

Conclusions

This analysis suggests that a business-as-usual scenario, where environmental concentrations of BFRs, such as PBDEs, are allowed to continue their increasing upward trend, especially in human mothers' milk, has the potential for very large human health and economic costs and consequences. These costs dwarf any defensible estimate of the benefits of continuing to use BFRs. This result, together with our most basic scientific understanding of the physico-chemical properties of these compounds, strongly supports the idea that we do not need these compounds free in the environment, and calls for precautionary action to eliminate the problem.[8]

References

1. J. de Boer, K. de Boer, J. P. Boon, in: Paasivirta, J. Editor, The Handbook of Environmental Chemistry Vol. 3, Part K. New Types of Persistent Halogenated Compounds. Springer-Verlag, Berlin, Heidelberg. Ch. 4, pp 61-95, 2000.
2. P. O. Darnerud, G.S. Eriksen, T. Johannesson, P.B. Larsen, and M. Viluksela, Environ. Health Perspec., 109, Supplement 1, 49, 2001.
3. J.A. Biesemeier. 2000. In: Alaee, M, Cannon C, Luross J, and Sergeant D. Editors, 2nd Annual Workshop on Brominated Flame Retardants in the Environment. National Water Research Institute, Environment Canada, Burlington, Ontario. Pp 28-54.
4. T.A. McDonald. 2002. Chemosphere 46. Pp 745-755.
5. P. Eriksson, E. Jakobsson, A. Fredriksson, Environ. Health Perspec.,109, 903, 2001.
6. C.A. de Wit. 2002. Chemosphere, 46, 583, 2002.
7. P. A. Arias, in the Second International Workshop on Brominated Flame Retardants. May 14-16, 2001. Stockholm University, Sweden.
8 Bergman, Ake. Organohalogen Compounds, Vol. 50, 2001, pp. 13-20.
9. M. DeVito, T. Zhou, M. Taylor, D. Ross, and K. Crofton. Organohalogen Comp., Vol. 53, 1, 2001.
10. Kellyn S. Betts. Environmental Science and Technology. February 1, 2002. Pp. 50A-52A.
11. J.L. Jacobson, S.W. Jacobson. New England J. Med., 335,783, 1986.
12. Tom Muir, Mike Zegarac. Environ. Health Perspec., Volume 109, Supplement 6, 885, 2001.
13. D. Burtraw and A. Krupnick. In, Revealing the Economic Value of Protecting the Great Lakes. Washington, DC: The Northeast-Midwest Institute and the National Oceanic and Atmospheric Administration, pp. 167-189, 2001.
14. Cheminfo Services Inc. A Technical and Socioeconomic Comparison of Options to Products Derived From the Chlor-alkali Industry. Prepared for Environment Canada, November, 1997.