BROMINATED FLAME RETARDANTS – ISSUES ARISING FROM AUSTRALIAN HUMAN HEALTH RISK ASSESSMENTS

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Introduction
The properties of at least some of the brominated flame retardants (BFRs) require their use to be closely controlled. The types of controls over use of individual chemicals can range from self-regulatory controls such as product stewardship through to strict regulatory measures. Chemical assessment is essential in informing the development of an appropriate management regime.

In Australia, the BFRs are considered to be "industrial chemicals". A number of BFRs are found on the Australian Inventory of Chemical Substances (AICS), and are therefore considered to be existing chemicals. Regulatory controls over existing chemicals are generally imposed following assessments by NICNAS.

Some BFRs, such as polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD), have been shown to be persistent and bioaccumulative, and are found in human biomonitoring studies. Some PBDEs (pentabromodiphenyl ether, pentaBDE, and octabromodiphenyl ether, octaBDE) and HBCD have been considered under the Stockholm Convention and found to be persistent organic pollutants (POPs). For this reason, the assessment of potential controls for these chemicals was considered to be a priority.

Assessments of BFRs
NICNAS has released three assessment reports on BFRs to date, with three additional reports still to be completed. Polybrominated flame retardants (PBFRs) were declared Priority Existing Chemicals (PECs) for preliminary assessment as a group of chemicals during 2000, primarily due to concerns over the bioaccumulative and persistent nature of some of the PBFRs which therefore have the potential to impact adversely on the environment and human health. This assessment had the aim of establishing which BFRs most required further assessment. The report was published in 2001 (NICNAS, 2001). The findings showed that hexabromocyclododecane (HBCD), decabromodiphenyl ether (decaBDE) and tetrabromobisphenol A (TBBPA) had the highest potential for use in Australia.

Full assessments of these three BFRs were commenced in 2005 Assessment of further two BFRs,octaBDE and pentaBDE, was commenced in 2006 due to a need to obtain assessment information to inform Australia's response to the Stockholm Convention consideration of these chemicals.

While these assessments were underway, a report on the occurrence of a mix of PBDE congeners found in human serum in Australia was published (Harden et al, 2005). The data that was collected as part of the assessment of the three PBDE mixtures was used together with biomonitoring results to determine the likely human health consequences resulting from the biomonitoring findings (NICNAS, 2007).

The assessment of HBCD was completed this year and the report has been published (NICNAS, 2012). The assessment report on decaBDE will also be released this year, followed by pentaBDE and TBBPA. Importation of pentaBDE has been banned as an interim measure pending the final recommendations of the assessment of this chemical. No report will be prepared on octaBDE, as this was removed from AICS because it was found to not be in use in Australia.

Discussion
A number of important issues have been identified through the assessment of the BFRs, leading to new assessment approaches and methodologies. This presentation will focus on these specific issues and how they impact on assessment of BFRs.

Exposure pathways
Major differences in the exposure pathways for PBDEs compared with previous POPs such as polychlorinated biphenyls (PCBs) have been identified. Exposure to the PBDEs has been established to be mostly via local sources, such as the presence of articles containing the PBDEs, such as foam furniture, within individual houses (Allen et al, 2008; Webster et al, 2009). Exposure pathways have been further elucidated and this has shown the

importance of household dust as an exposure source for these chemicals (Jones-Otazo et al, 2005; Lorber, 2008). This is in contrast to the legacy POPs, where food exposure following dispersion in the general environment and bioaccumulation through the food chain is generally a major pathway (Jones-Otazo et al, 2005).

The concentration of PBDEs in household dust has been shown to be highly variable, both between countries and between individual premises in a single country (NICNAS, 2007; NICNAS 2012). The extreme variability in exposure, covering several orders of magnitude, gives rise to a broad spectrum of public risk within a single country. This has been found both for HBCD and for the PBDEs.

Use of biomonitoring results
Widespread biomonitoring of human serum, adipose tissue and breast milk has been undertaken for PBDEs. As many important PBDE congeners are persistent and bioaccumulative, it is difficult to use deterministic exposure estimates by themselves in human health risk assessments. It is however possible to use these in conjunction with biomonitoring results to develop a model to relate the conditions under which humans are exposed to the expected levels of the persistent and bioaccumulative chemicals in the human body (Lorber, 2008). Such modeling is likely to be a reasonably accurate description of the relationship of PBDE exposure and levels in body tissues, as the close relationship between home environment and breast milk has been demonstrated in one experimental study (Wu et al, 2007).

In addition, the availability of high quality toxicokinetic data in animals enables direct comparison between concentrations in animal tissues under dosing conditions and levels in human tissues, allowing risk estimation directly from the biomonitoring results (NICNAS, 2007). This assessment found that there was not sufficient Margin of Exposure for neurodevelopment in foetuses and infants to conclude that the human exposure in Australia was at safe levels according to the results of Harden et al (2005), and led to a prohibition on the introduction of pentaBDE into Australia in 2007. Recent data (Toms et al, 2012) has demonstrated significant reductions of PBDE levels in breast milk and the serum of infants since this time.

Toxicological mode of action
A wide range of experimental studies is available for some of the BFRs, particularly some PBDEs. A reasonable proportion of the mode of action for toxicity for some of the BFRs can be postulated based on the results of these studies. The mode of action for PBDEs is clearly different to the dioxin like mode of action established for some PCBs. This is not unexpected, as the chemical similarity between PBDEs and coplanar PCBs (having a dioxin like mode of action) is little more than superficial. Coplanar PCBs have a fully delocalized, planar structure, while the oxygen bridge in PBDEs constrains the rings to be non-coplanar and removed the delocalization.

However a stronger resemblance exists between PBDEs and non-coplanar PCBs, although there are still distinct structural differences. Toxicological studies indicate that there appear to be similarities in mammalian responses to PBDEs and non-coplanar PCBs. A mode of action involving upregulation of some liver metabolic enzymes, followed by increased metabolism and excretion of thyroxine, and neurodevelopmental effects resulting from hypothyroidism in critical developmental windows appears to be common between these two classes of chemicals (NICNAS, 2007). Certain toxicological results for HBCD also indicate that this mode of action might also be relevant in this case.

The consistency of findings between PBDEs and non-coplanar PCBs across major elements of the mode of action allows conclusions to be drawn about the human relevance of findings for PBDEs based on findings in humans exposed to high levels of PCBs.

Articles
A key regulatory issue arises because the main exposure route for PBDEs and HBCD is release from treated articles. . In Australia, it is anticipated that the importation of BFRs in finished articles greatly outweighs the importation of BFRs in the form of chemical products.

In the assessment of BFRs, it is possible to use available information to determine the direct link between the introduction of articles and a quantitative estimate of human health risk. This may allow control measures to be closely targeted to the types of articles which give rise to the greatest risk.

The following chain of links is among those which can be established:

PentaBDE in furniture foam

(Allen et al, 2008)

PBDE congeners in dust

(Wu et al, 2007)

Biomonitoring results

(NICNAS, 2007)

Human health risk

Analysis of the links from PBDEs in articles to the potential for adverse health effects informs the formulation of recommendations in the NICNAS assessments, and can be used by the implementing agency for the Stockholm Convention in Australia, the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) in preparing appropriate risk management measures.

References

Allen JG, McClean MD, Stapleton HM, Webster TF (2008) Linking PBDEs in house dust to consumer products using X-ray fluorescence. Environ Sci Technol. 42(11):4222–8

Harden F, Müller J, Toms L (2005) "Organochlorine pesticides (OCPs) and polybrominated diphenyl ethers (PBDEs) in the Australian population: Levels in human milk" Environment Protection and Heritage Council of Australia and New Zealand. http://www.ephc.gov.au/pdf/EPHC/OCP_PBDE_human_milk_jan 2005.pdf

Jones-Otazo HA, Clarke JP, Diamond ML, Archbold JA, Ferguson G, Harner T, Richardson GM, Ryan JJ, Wilford B (2005) "Is house dust the missing exposure pathway for PBDEs? An analysis of the urban fate and human exposure to PBDEs" Environ Sci Technol 39, 5121-5130

Lorber M (2008) Exposure of Americans to polybrominated diphenyl ethers. J Expo Sci Environ Epidemiol. 18(1):2–19

NICNAS (2001) "Polybrominated Flame Retardants: Priority Existing Chemical Assessment Report No. 20", http://www.nicnas.gov.au/Publications/CAR/PEC/PEC20/PEC_20_Full_Report_PDF.pdf

NICNAS (2007) "Interim Public Health Risk Assessment of Certain PBDE congeners", http://nicnas.gov.au/Publications/CAR/Other/Final%20Interim%20Report%20-%20March.pdf

NICNAS (2012) Priority Existing Chemicals Report on HBCD, available at http://nicnas.gov.au/Publications/CAR/PEC.asp

Toms LL, Guerra P, Eljarrat E, Barceló D, Harden FA, Hobson P, Sjodin A, Ryan E and Mueller JF (2012) Brominated flame retardants in the Australian population: 1993–2009, Chemosphere, Available online 28 June 2012, ISSN 0045-6535, 10.1016/j.chemosphere.2012.05.053.

Webster TF, Harrad S, Millette JR, Holbrook RD, Davis JM, Stapleton HM, Allen JG, McClean MD, Ibarra C, Abdallah MA and Covaci A (2009) Identifying transfer mechanisms and sources of decabromodiphenyl ether (BDE 209) in indoor environments using environmental forensic microscopy. Environ Sci Technol. 43(9):3067–3072

Wu N, Herrmann T, Paepke O, Tickner J, Hale R, Harvey LE, La Guardia M, McClean MD, Webster TF (2007) Human exposure to PBDEs: associations of PBDE body burdens with food consumption and house dust concentrations. Environ Sci Technol. 2007;41(5):1584–9