Halogenated Flame Retardants in Consumer Products: Do the Fire Safety Benefits Justify the Health and Environmental Risks?

Arlene D. Blum[1] and Linda Birnbaum[2]
[1] University of California, Berkeley, Green Science Policy Institute, 1492 Olympus Avenue, Berkeley, California 94708
[2] U.S. National Institute of Environmental Health Sciences and National Toxicology Program, P.O. Box 12233 Mail Drop B2-01, Research Triangle Park, North Carolina 27709

Introduction

Beginning in the 1970's, increasingly severe flammability standards in the United States were met with brominated or chlorinated flame retardants without consideration of potential adverse health or environmental impacts. Since then a series of toxic, persistent, and/or bioaccumulative halogenated flame retardants have been removed from use, only to be replaced by others with similar properties (Blum 1977, , 2007, Gold 1978). The continued use of certain halogenated flame retardants in consumer products should be questioned as current research suggests they have the potential to contribute to serious long term health problems, while providing only limited fire safety benefits.

In 1977 the U. S. Consumer Product Safety Commission (CPSC) banned brominated Tris [tris (2,3-dibromopropyl) phosphate] from children's sleepwear after it was found to be a mutagen, a carcinogen, and absorbed into children's bodies (CPSC 1977). The main replacement for brominated Tris was chlorinated Tris or TDCP, [tris (1,3-dichloro-2-propyl) phosphate]. After also being found to be a mutagen, chlorinated Tris was removed from use in sleepwear in 1978, but is currently used in furniture and juvenile product foam (nursing pillows, baby carriers, high chairs, etc.) to meet California Technical Bulletin 117 (TB117). Recent studies show chlorinated Tris and other organohalogen flame retardants can migrate from products into dust, a likely route of human exposure (Wu et al. 2007, Stapelton et al. 2009). The CPSC estimates the lifetime cancer risk from Tris-treated furniture foam is up to 300 cancer cases/million (Babich 2006).

TB117 is a unique California flammability standard that requires polyurethane foam to withstand exposure to a small open flame for twelve seconds. From its implementation in 1975 until 2004, this standard was primarily met with penta-brominated diphenyl ether (pentaBDE). PentaBDE and other polybrominated diphenyl ethers (PBDEs) are structurally similar to known human toxicants polybrominated biphenyls (PBBs), polychlorinated biphenyls (PCBs), dioxins and furans (Figure 1). In addition to having similar mechanisms of toxicity in animal and human studies (Birnbaum et al. 2003), PBDEs also persist and bioaccumulate in humans and animals (Hites 2005). In 1999, 98% of global pentaBDE usage was in North America, in large part to meet TB117 (Hale et al. 2003). PentaBDE was banned in California in 2003; eight other states and the European Union (EU) followed suit (Blum 2007). In 2004 Chemtura, the sole U.S. manufacturer, voluntarily ceased production, and in 2009 pentaBDE and octaBDE were listed as persistent organic pollutants under the Stockholm Convention (UNEP 2009). Late in 2009, after negotiations with the U.S. EPA, the three manufacturers of decaBDE agreed to cease production within three years. However decabrominated diphenylethane (DBDPE), a major substitute for decaBDE, is similar in structure, persistence and bioaccumulation (Betts 2008). PBDEs continue to increase in humans, animals, and the food supply, moving from consumer products in homes into dust and the environment (Shaw & Kurunthachalam 2009).

According to the furniture and the polyurethane foam industry, all furniture sold in California and about 30% of furniture sold in the U.S. and in Canada outside of California complies with TB117 (Luedeka, Batson). A major replacement for pentaBDE, used in furniture and baby product foam today, is Firemaster 550, produced by Chemtura. In 2004, the U.S. EPA requested health information on Firemaster 550 based on its predicted reproductive, neurological, and developmental toxicity and persistent degradation products (EPA Furniture Flame Retardancy Partnership. 2005). While awaiting the test results and their evaluation during the past five years, the EPA has allowed Firemaster 550 to continue to be used.

Firemaster 550 components include: (1) triphenyl phosphate (highly eco-toxic); (2) triaryl phosphate isopropylated (probable reproductive toxin); (3) 2-ethylhexyl-2,3,4,5-tetrabromobenzoate; (4) Bis (2-ethylhexyl) tetrabromophthalate (Stapleton et al. 2008). The components have been found in dust, sewage sludge (Klosterhaus et al. 2008) and sediment in California as well as in marine mammals near flame retardant production facilities in China (Lam 2009).

Thus, a series of toxic or untested brominated and chlorinated flame retardant chemicals continue to be used in consumer products in close contact with humans, without adequate consideration of their health and environmental impact. The present study investigates flammability regulations for some consumer products in North America, and discusses the fire safety benefits they provide, the toxicity of the chemicals that have been used to meet them, and how alternative strategies can reduce fire hazard without adding potential persistent organic pollutants to consumer products.

Methods

Methods consisted of reviewing the literature and interviewing leaders in industry, government, and the private sector on the following topics: major uses of halogenated flame retardant chemicals; exposure and health impacts; regulations leading to the uses of flame retardants; fire safety data showing impacts of flame retardant chemicals in consumer products; and policy decisions regarding flame retardant chemicals

Results and Discussion

Major uses of halogenated flame retardant chemicals

The major uses of halogenated flame retardant chemicals in North America are in 1) electronics, 2) building insulation, 3) transportation, and 4) home furnishings. The chemicals are commonly used at levels up 5 % of the weight of polyurethane foam and 15% of the weight of the plastic of electronic housings (Allen et al. 2008).

Exposure and health impacts

Halogenated flame retardants are the predominant class of toxic chemical found in human biomonitoring studies (Houlihan et al. 2005). They are semi-volatile and can form thin films on walls and windows (Weschler & Nazaroff 2008). Toddlers have much higher body burdens of pentaBDE than their mothers (Toms et al. 2008). Californians have higher levels in their house dust and body fluids than residents of other states (Zota et al. 2008).

Many halogenated flame retardants have been shown to cause cancer, immune and endocrine disruption, and adverse reproductive and neurodevelopmental effects in animals (Birnbaum et al. 2003). In humans, these substances are associated with reproductive abnormalities (Meeker & Stapleton 2009), diabetes (Lim et al. 2008), thyroid dysregulation (Turyk et al. 2008, Meeker et al. 2009), cognitive changes (Roze et al. 2009, Herbstman et al. 2010), and cryptorchidism (undescended testicles) (Main et al. 2007). Since the

1970s, brominated flame retardants have increased in use and, at present, PBDE levels in marine biota and people from North America are the highest in the world, reflecting the unique flammability standards leading to the use of these compounds in the U.S. (Shaw & Kurunthachalam 2009).

Halogenated flame retardants also pose recycling and end of life problems**.** When products treated with these chemicals are exported to developing countries, they are often burned in the open, leading to the production of brominated and chlorinated dioxins and furans (Zennegg et al. 2009, Wong et al. 2007) and the release of PBDEs, other BFRs and toxics (Wong et al. 2007). When landfilled, they can leach into water and soil (Danon-Schaeffer et al. 2008) and make their way into food (Melber & Kielhorn 1998).

Fire safety data showing impacts of flame retardant chemicals in consumer products

The use of flame retardant chemicals in consumer products has not been shown to reduce fire deaths in the peer-reviewed literature. U.S. National Fire Protection Association (NFPA) data does not show a greater reduction in the rate of fire deaths in California than in other states that do not have furniture flammability standards (Figure 2).

Reducing ignition sources can prevent fires without adding potentially hazardous chemicals to consumer products. A 60% decrease in fire deaths in the United States since 1980 parallels the decrease in per capita cigarette consumption (Diekman & Ballesteros 2008, Ahrens 2008), increased enforcement of improved building, fire, and electrical codes; and the increased use of smoke detectors and sprinklers. An estimated 65% of reported home fire deaths in 2000-2004 resulted from fires in homes without working smoke alarms (Ahrens 2008).

Recent laws mandating fire-safe cigarettes and a voluntary industry standard for fire-safe candles promise further reductions in fire death and injury. The European Union and 44 U.S. states have passed legislation requiring fire-safe cigarettes.

Regulations leading to the uses of flame retardants and how they are met

TB 117 for filling materials in upholstered furniture and juvenile products is primarily met by the addition of halogenated chemicals. California TB 133, a severe flammability standard for furniture for use in public occupancies, is met by the use of higher density foam which is less flammable and the flame retardant melamine, often mixed with chlorinated Tris or TDCP. The severe new U.S. flammability standard for mattresses, CFR 1633, is met by a barrier technology where flame-retardant polymeric fabrics are wrapped around the foam to serve as a barrier to ignition. The CPSC estimates that this standard will prevent 78% of deaths from fires that originate in mattresses (CPSC Release 2006). A related technology could be used to protect the foam inside furniture from ignition. Other design alternatives, such as making electronics of metal, glass, or ceramics instead of plastics, can reduce flammability without chemicals (Betts 2008).

Policy decisions regarding flame retardant chemicals

Prior to implementing new flammability regulations leading to halogenated chemicals in consumer products, decision makers should consider health and environmental hazards of the chemicals and materials likely to be used, as well as proven fire safety benefits.

Flammability regulations can be designed to be met without flame retardant chemicals. For example, the CPSC is moving forward with a staff draft federal furniture standard that addresses fire safety without the use of added chemicals in polyurethane foam (CPSC 2008). A previous CPSC draft flammability standard, similar to TB117, was removed from consideration due in part to health and environmental concerns (Moore 2007). Strategies to reduce fire hazard without potential adverse health impacts include new technologies and materials, product design, and green chemistry. Reducing the use of untested halogenated compounds with a potential to be persistent organic pollutants will protect human and animal health and the global environment.

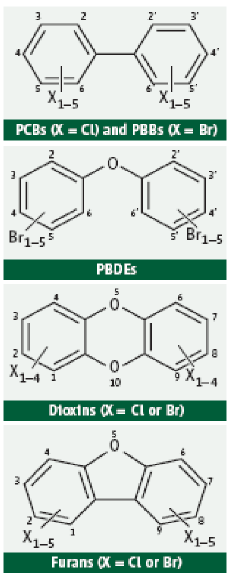

Figure 1. PBDEs are structurally similar to PBB, PCBs, dioxins and furans.

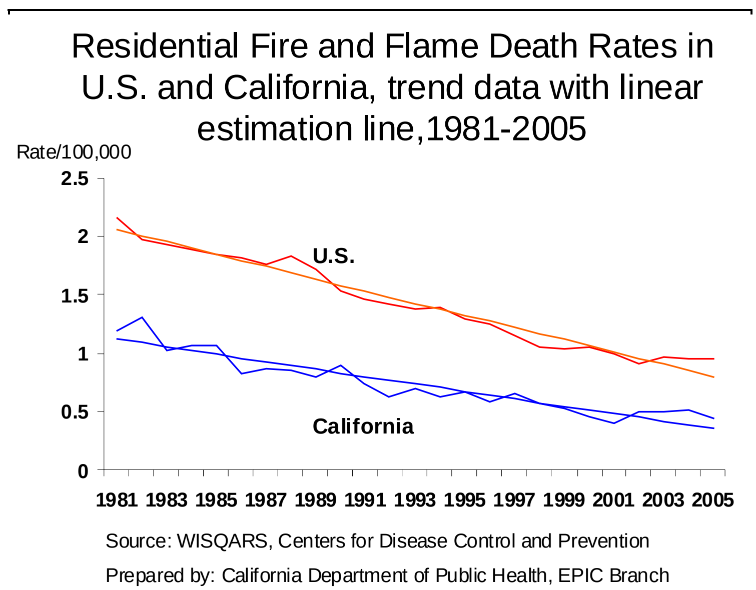

Figure 2. Residential Fire Death Rates 1981 -2005

The Research described was reviewed by the National Institute of Environmental Health Sciences, and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does the mention of trade names or commercial products constitute an endorsement or recommendation.

References

Ahrens M. 2008. 2008. Fire Technology 44.

Ahrens M. 2008. National Fire Protection Association, Quincy, MA. May.

Allen JG, Mcclean MD, Stapleton HM, Webster TF. 2008. Environ. Sci. Technol 42 4222-4228.

Babich MA. 2006. CPSC Staff Preliminary Risk Assessment of Flame Retardant (FR) Chemicals in Upholstered Furniture Foam.

Betts KS. 2008. Environmental Health Perspectives 116(5): A211.

Birnbaum LS, Staskal DF, Diliberto JJ. 2003. Environnent International 29(6): 855.

Blum A. 1977. Science (4273):17-23.

Blum A. 2007. Science 318: 194.

California Bureau of Thermal Insulation and Home Furnishings. 1990. Technical Bulletin 117, 1975.

CPSC.Standard for the Flammability of Residential Upholstered Furniture.2008. Federal Register 16 CFR Part 1634. Mar 4, 2008.

US Consumer Product Safety Commission Release #06-091 February 16, 2006.

CPSC 1977. http://www.cpsc.gov/cpscpub/prerel/prhtml77/77030.html.

Danon-Schaeffer MN, Grace JR, Ikonomou MG. 2008. Organohalogen Compounds 70 365-368.

Diekman ST, Ballesteros MF, Berger LR, Kegler SR. 2008. Inj Prev 14: 228.

Gold MD 1978. Science (4343):785-7.

Hale RC, Alaee M, Manchester-Neesvig JB, Staplton HM, Ikonomou MG. 2003. Environment International 29:6, 771-779.

Herbstman JB, Sjödin A, Apelberg BJ, Witter FR, Halden RU, Patterson DG, Jr., Panny SR, Needham LL, Goldman LR. 2008. Environ Health Perspect 116(10): 1376.

Hites RA. 2005. Environ SciTechnol 38(4):945.

Houlihan J, Kropp T, Wiles R, Gray S, Campbell C. 2005. Environmental Working Group.

The Coalition for Fire Safe Cigarettes. 2010. http://firesafecigarettescoalition.org.

EPA, Furniture Flame Retardancy Partnership (EPA 742-R-05-002A, September, 2005).

Klosterhaus S, Konstantinov A, Stapleton HM. 2008. Presentation at the 10th Annual Workshop on Brominated Flame Retardants. Victoria, British Columbia, Canada.

Lam JCW, Lau RKF, Margaret BM, Lam PKS. 2009. ES&T, 43(18): 6944.

Lim JS, Lee DH, Jacobs DR Jr. 2008. Diabetes Care 31(9):1802.

Luedeka R, Polyurethane Foam Ass. and Batson R. American Home Furnishings Ass. Personal communication.

Main KM, Kiviranta H, Virtanen HE, Sundqvist E, TuomistoJT, Tuomisto J, Vartiainen T, Skakkebæk NE, Toppari1 J. 2007. Environ Health Perspect 115(10): 1519.

Meeker JD, Johnson PI, Camann D, Hauser R. 2009. Science of the Total Environment 407(10): 3425.

Meeker JD, Stapleton HM. 2009. Environ Health Perspect. doi: 10.1289/ehp.

Melber C, Kielhorn J. 1998. Environmental Health Criteria 205.

Moore TH. 2007. http://www.cpsc.gov/pr/moore122707.html.

Roze E, Meijer L, Bakker A, Van Braeckel KNJA, Sauer PJJ, Bos AF. 2009. Environ Health Perspect doi: 10.1289/ehp.0901015 (available at http://dx.doi.org/).

Shaw SD, Kurunthachalam K. 2009. Reviews on Environmental Health 24: 157.

Stapleton HM, Allen JG, Kelly SM, Konstantinov A, Klosterhaus S, Watkins D, McClean MD, Webster TF. 2008. Environ SciTechnol 42(18): 6910.

Stapelton, HM, Klosterhaus S, Eagle S, Fuh J, Meeker JD, Blum A, Webster, TF. 2009. ES& T43: 7490.

Toms LM, Harden F, Paepke O, Hobson P, Ryan JJ, Mueller JF. 2008. Environ SciTechnol 42(19): 7510.

Turyk ME, Persky VW, Imm P, Knobeloch L, Chatterton R, Jr., Anderson HA. 2008. EHP 116(12): 1635.

UNEP (2009) Report of the Conference of the Parties of the Stockholm Convention on Persistent Organic Pollutants on the work of its fourth meeting. UNEP/POPS/COP.4/38.

Weschler CJ, Nazaroff WW. 2008. Atmospheric Environment. 42(40): 9018.

Wong MH, Wu SC, Deng WJ, Yu XZ, Luo Q, Leung AOW, Wong CSC, Luksemburg WJ, Wong AS. 2007. Environmental Pollution 149 (2007) 131e140.

Wu N, Herrmann T, Paepke O, Tickner J, Hale R, Harvey E, La Guardia M, McClean MD, Webster TF. 2007. Environ. Sci. Technol 2007 41(5): 1584.

Zennegg M, Yu X, Wong MH, Weber R. 2009. Organohalogen Compounds 71 2263-2267.

Zota AR, Rudel RA, Morello-Frosch RA, Brody JG. 2008. Environ Sci Technol 42(21): 8158.