Nomination of FR Chemicals for NTP Testing

U.S. Consumer Product Safety Commission (CPSC) Staff*

August 1, 2005

Introduction

Upholstered furniture fires are a leading cause of residential fire deaths involving consumer products. The U.S. Consumer Product Safety Commission (CPSC) is considering the development of a performance standard to reduce the potential for ignition of upholstered furniture by cigarettes and small open flames, such as matches, cigarette lighters, and candles (CPSC 2003). Based on 1995-1999 data, the CPSC staff estimates that annually 460 deaths, 1110 injuries, and $130 million in property damage could be addressed by the draft standard (Levenson 2004). While furniture manufacturers would be free to choose the means of complying with a possible standard, manufacturers have informed us that they are likely to treat some upholstery cover fabrics and other upholstery materials with flame retardant (FR) chemicals.

In addressing the hazards associated with upholstered furniture fires, the CPSC staff is working to develop a draft performance standard without creating additional health hazards to consumers, workers, or the environment. In 1998, the Fire Retardant Chemicals Association (FRCA) (now the American Fire Safety Council, AFSC) identified 16 FR chemicals or chemical classes that its members might market for use in upholstered furniture cover fabrics if a standard is promulgated (FRCA 1998). The CPSC staff reviewed all of the available toxicity data on the 16 chemicals/chemical classes, comprising over 50 individual compounds. The toxicity reviews were later updated to include new information (Bittner 2001; Bittner et al. 2001). The CPSC staff reviews contributed to a National Research Council (NRC) report on 16 FR chemicals, representing each of the 16 classes (NRC 2000).

In 2001, the CPSC staff completed risk assessments of selected FR chemicals, including: antimony trioxide (Sb_2O_3) (AT); decabromodiphenyl oxide (DBDPO); hexabromocyclododecane (HBCD); phosphonic acid, (3-{[hydroxymethyl]amino}-3-oxopropyl)-, dimethyl ester (PA) (sold under the trade name Pyrovatex®); and tetrakis (hydroxymethyl) phosphonium chloride (THPC) (Proban CC®) polymer (Babich and Thomas 2001). Four of these chemicals—AT, DBDPO, HBCD, and PA—are currently used in the United Kingdom (UK), where a flammability standard for upholstered furniture is in effect. Therefore, they may be used in the U.S. if a flammability standard is adopted. THPC also was included in the staff risk assessment, because it is currently used in apparel, and pre-production upholstery fabric samples were available for testing.

With respect to upholstery FR's in general, the CPSC staff is cooperating with the U.S. Environmental Protection Agency (EPA) to develop a possible significant new use rule (SNUR) on the use of FR chemicals in upholstered furniture. The CPSC staff is also participating in a workgroup with the EPA Design for the Environment (DfE) Program. The DfE workgroup is reviewing the potential risks associated with substitutes for pentabromodiphenyl ether (penta-

* The following comments are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

BDE). Penta-BDE was the principal FR chemical for flexible polyurethane foam (PUF) used in upholstered furniture. The sole U.S. producer of penta-BDE voluntarily ceased production in 2004 due to concerns about its accumulation in the environment and in human tissue. The European Union and the state of California have banned the production and/or use of penta-BDE and octabromodiphenyl ether (octa-BDE). The EPA has proposed a SNUR for penta- and octa-BDE.

In addition to upholstered furniture, CPSC is considering flammability standards for mattresses and bedding to address small open flame ignitions (CPSC 2004). The state of California is developing flammability standards for upholstered furniture and mattresses. FR chemicals are already used in a variety of products, including televisions, personal computers, carpet, automobile interiors, and infant sleepwear. Recently, the EPA DfE program organized a second workgroup to review the potential risks associated with FR chemicals and barriers for use in mattresses.

The CPSC staff requests that the National Toxicology Program consider performing toxicity tests on selected FR chemicals, as described below.

Antimony Trioxide (Sb_2O_3) (AT) (1309-64-4)

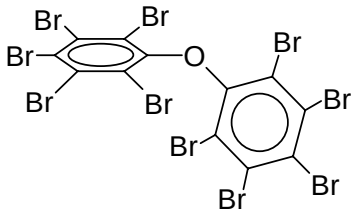
Antimony trioxide (AT) is a synergist, that is, it is used in combination with halogenated flame retardants, such as decabromodiphenyl oxide. Worker and consumer exposure may occur from FR-treated automobile interiors, infant sleepwear, and home furnishings (FRCA 1998; WHO 1997). Dermal, inhalation, and oral exposure are possible.

The toxicology of AT has been reviewed by the National Research Council (NRC 2000) and the CPSC staff (Babich et al. 2004; Bittner 2001; Bittner et al. 2001; Hatlelid 1999). No lifetime feeding studies are available (Table 1). Sub-chronic studies showed systemic effects (gastrointestinal, hepatic, and hematological effects) at relatively high doses. Inhalation of dusts leads to cancer and non-cancer lung effects in rats. Lung cancer in rats has been attributed to inhalation of "inert particles." In humans, non-cancer effects occur, but the risk of lung cancer risk is inconclusive due to limited size and follow-up. Risk assessments performed by NRC and the CPSC staff suggest that inhalation of dusts containing AT may be of concern (Babich & Thomas 2001; NRC 2000).

The CPSC staff requests the following studies for AT:

- Chronic oral study in rat and/or mouse
- Chronic inhalation study in a second species, such as the hamster.

Decabromodiphenyl Oxide (DBDPO) (1163-19-5)



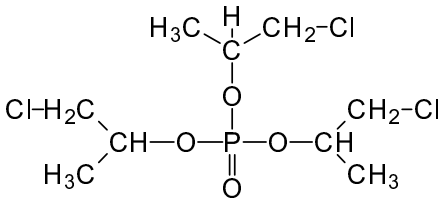
Decabromodiphenyl oxide (DBDPO) is an economically important flame retardant that is used in FR-treated high-impact polystyrene (HIPS), electronic equipment, automobile interiors, infant sleepwear, and home furnishings (Birnbaum & Staskal 2004; FRCA 1998; WHO 1997). DBDPO is applied to upholstery and automobile interior cover fabrics in the form of an acrylic or vinyl back-coating. DBDPO is applied to apparel with a polymeric binder (Mischutin 1975). DBDPO is generally used in combination with antimony trioxide. The toxicology of DBDPO has been reviewed (Babich et al. 2004; BFRIP 2003; Birnbaum & Staskal 2004; Bittner 1999a, 2001; Bittner et al. 2001; Hardy 2002; NRC 2000). Adverse effects in the thyroid and liver were observed in rats and mice fed relatively high DBDPO doses in chronic studies (Table 1).

Recently, it has been reported that DBDPO (Viberg et al. 2003a) and lower brominated congeners (Branchi et al. 2002, 2003; Eriksson et al. 2002; Viberg et al. 2002a; Viberg et al. 2003b) may be developmental neurotoxicants in mice, based on changes in spontaneous behavior tests (locomotion, rearing, and total activity) in mice dosed prenatally. However, there are a number of limitations to these studies, and their relevance to human health is uncertain (BFRIP 2003; Birnbaum and Staskal 2004; Eriksson and Viberg 2004; Vijverberg and van den Berg 2004).

The CPSC staff requests the following studies for DBDPO:

- Developmental neurotoxicity studies in rats using established protocols, such as OPPTS 870.6300 (EPA 1998).

Tris(chloropropyl) Phosphate (TCPP) (Mixture of Isomers) (13674-84-5; 76025-08-6; 76649-15-5; 6145-73-9)



Tris(chloropropyl) phosphate (TCPP) has been proposed as a substitute for pentabromodiphenyl ether (penta-BDE) in flexible polyurethane foam (PUF) used in FR-treated home furnishings. Limited toxicity data are available (Bittner 1999d, 2001; Bittner et al. 2001; Ferrante 1999b; NRC 2000) (Table 1). However, some structurally-related compounds are carcinogenic, including tris(1,3-choropropyl-2) phosphate (13674-87-8) and tris(2,3-dibromopropyl) phosphate (126-72-7).

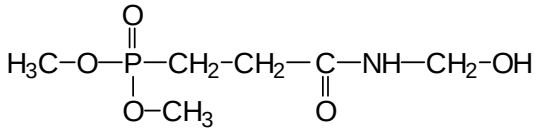
It should be noted that there has been some confusion in the literature regarding the structure and identity of TCPP (reviewed in Saltzman & Babich 1999). TCPP has been inaccurately referred to as tris(2-chloro-1-propyl) phosphate (6145-73-9), which is a minor component of the commercial product. Both tris(1-chloro-2-propyl) phosphate (13674-84-5) (structure shown) and tris(2-chloro-1-propyl) phosphate (6145-73-9) have been reported to be high production volume chemicals. However, the commercial product is a mixture of isomers containing 57-to-83% tris(1-chloro-2-propyl) phosphate (13674-84-5) (structure shown), 16-to-35% bis(1-chloro-2-propyl) 2-chloro-1-propyl phosphate (76025-08-6), 1-to-7% bis(2-chloro-1-propyl) 1-chloro-2-propyl) phosphate (76649-15-5), and less than 1% tris(2-chloro-1-propyl) phosphate (6145-73-9).

The CPSC staff requests the following studies for TCPP:

- Sub-chronic and chronic oral studies in rat and/or mouse.

Phosphonic acid, (3-{[hydroxymethyl]amino}-3-oxopropyl)-, dimethyl ester (PA) (20120-33-6)

Phosphonic acid, (3-{[hydroxymethyl]amino}-3-oxopropyl)-, dimethyl ester (PA) is a reactive flame retardant used with cellulosic fabrics, including children's sleepwear and upholstered furniture (FRCA 1998; WHO 1997). PA is typically applied in a solution that contains a durable press resin such as trimethylol melamine, phosphoric acid, and ethyleneurea (D'Ruiz 1998; Sanders 1978). The fabric is then dried, heat-cured, and washed. PA thus becomes covalently bound to cellulosic hydroxyl groups and/or the resin (D'Ruiz 1998; Sanders 1978). Unidentified organophosphorus compounds are released when treated fabrics are extracted with aqueous solutions (Cobb 2000; see also Babich & Thomas 2001). These may include cleavage products of PA and/or PA-melamine adducts. The toxicology of PA has been reviewed by the CPSC staff (Babich et al. 2004; Bittner 1999b, 2001; Bittner et al. 2001) and the NRC (NRC 2000). Toxicity data are limited to a 28-day study with incomplete pathology (Table 1).

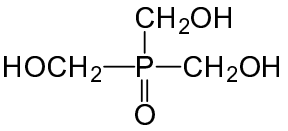


The CPSC staff requests the following studies for PA:

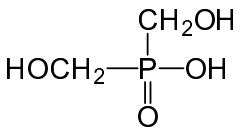
- Sub-chronic oral studies in rat and/or mouse
- Chronic oral studies in rat and/or mouse, depending on the outcome of sub-chronic studies
- Percutaneous absorption studies in rat and/or mouse

By-product and Metabolite of Tetrakis(hydroxymethyl) Phosphonium Chloride (THPC) (124-64-1):

Tris(hydroxymethyl) phosphine oxide (THPO) (1067-12-5)

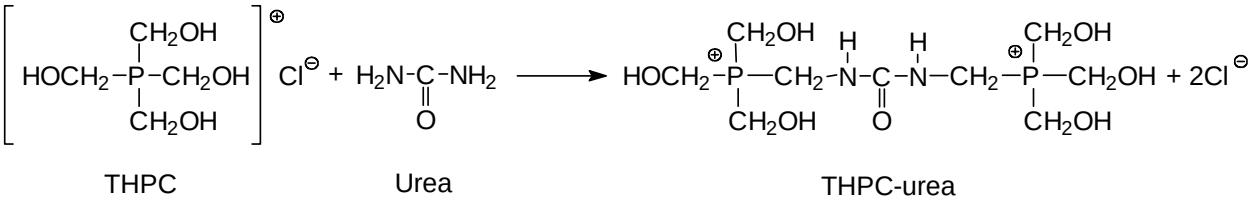


THPO

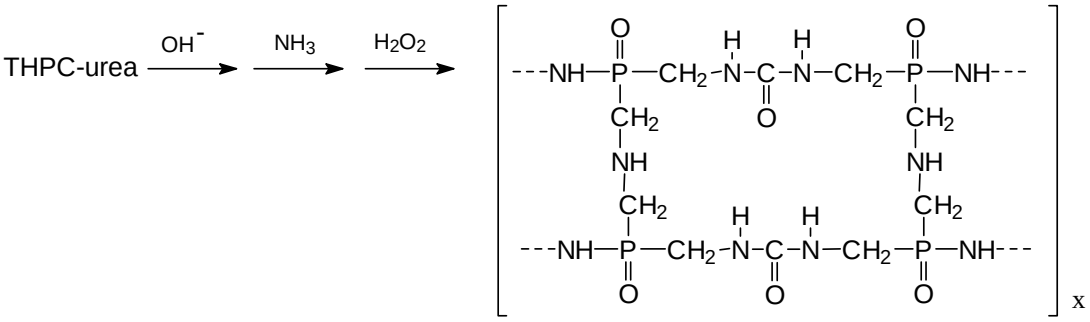


BHPA

Tetrakis(hydroxymethyl) phosphonium chloride (THPC) is a reactive flame retardant used with cellulosic and cellulosic blend fabrics, including FR-treated infant sleepwear and work clothes (FRCA 1998; WHO 1997). It has been proposed for use in upholstered furniture cover fabrics (FRCA 1998). THPC and several application methods were developed as a flame retardant for cotton at the Department of Agriculture, Southern Regional Research Center, New Orleans, LA. In a common commercial process, THPC is first combined with urea to form a 2:1 THPC: urea compound (pre-condensate) (Albright & Wilson 1998; Sanders 1978) (Figure 1). THPC then reacts further with anhydrous ammonia and hydrogen peroxide to form a cross-linked polymer that is physically bound to the fabric.



THPC Urea THPC-urea



THPC-urea polymer

Figure 1. Process for the application of THPC

Multiple organophosphorus compounds are released when treated fabrics are extracted with aqueous solutions (Cobb 2000; see also Babich & Thomas 2001). These compounds are reported to include tris (hydroxymethyl) phosphine oxide (THPO) and low molecular weight polymers (Baitinger 2000; Frank et al. 1982a,b; Loewengart & Van Duuren 1977; Martin 1998; Vail et al. 1982; WHO 2000). THPO and bis-hydroxymethylphosphinic acid (BHPA) are reported to be metabolites of THPC (WHO 2000).

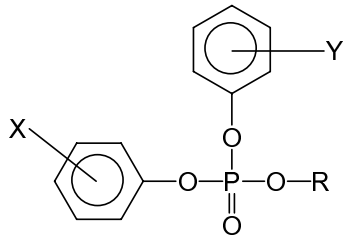
The parent compound, THPC, was toxic to the liver in sub-chronic studies in rodents (Babich et al. 2004; Bittner 1999c, 2001; Bittner et al. 2001; NRC 2000) (Table 1). Little is known regarding the toxicity of THPO. THPO was not mutagenic in Salmonella (MacGregor et al. 1980) and did not inhibit acetyl cholinesterase in vitro (reviewed in WHO 2000).

The CPSC staff requests the following studies for THPO:

- Sub-chronic oral studies in rat and/or mouse
- Chronic oral studies in rat and/or mouse, depending on the outcome of sub-chronic studies
- Percutaneous absorption studies in rat and/or mouse

Aromatic Phosphates:

t-Butylphenyl diphenyl phosphate (BPDP) (56803-37-3)
2-Ethylhexyl diphenyl phosphate (EHDP) (1241-94-7)
Isodecyl diphenyl phosphate (IDDP) (29761-21-5)
Phenol isopropylated phosphate (PIP) (68937-41-7)
Tricresyl phosphate (TCP) (isomers) (1330-78-5)
Triphenyl phosphate (TPP) (115-86-6)



R = aryl or alkyl

Aromatic phosphates are flame retardant chemicals used in flexible polyurethane foam (PUF) used in FR-treated home furnishings (FRCA 1998; WHO 1997). They may also be used to treat upholstery cover fabrics in the form of a back-coating (FRCA 1998). Workers may be exposed to aromatic phosphates by inhalation of vapor or dusts.

The CPSC staff requests the following studies for representative aromatic phosphates to be selected by NTP:

- Sub-chronic/chronic studies in rat and/or mouse
- Neurotoxicity and/or developmental neurotoxicity studies

Table 1. Toxicity of Selected Flame Retardant Chemicals[a, b]

Chemical/Class	CAS no.	Availability of Toxicity Data							Chronic Health Effects				
		Acute	Subchronic	Chronic	Repro/Dev	Neurotox	Genetox	Human	Chronic Toxicity[c]	Endpoint[d]	NOAEL/ LOAEL[e] (mg/kg-d)	UF	ADI (mg/kg-d)
Antimony trioxide (AT)	1309-64-4	X	X	-	-	-	X	-	B	O	230	100	2.3
Inhalation		-	X	X	X	-	-	X	B	C,O	9 μg/m^3 L	1,000	9 ng/m^3
Decabromodiphenyl oxide (DBDPO)	1163-19-5	X	X	X	X	-	X	-	B	O	3,200 L	1,000	3.2
Tris(chloropropyl) phosphate (TCPP) (mixture of 4 isomers)	13674-84-5 76649-15-5 76025-08-6 6145-73-9	X	-	-	-	-	X	-	I				ND
Phosphonic acid, (3-{[hydroxymethyl] amino}-3-oxopropyl)-, dimethyl ester (PA) (Pyrovatex®)	20120-33-6	X	?	-	-	-	X	-	I				ND
Tetrakis(hydroxymethyl) phosphonium salts (THPX) (Proban®):													
Chloride salt (THPC)	124-64-1	X	X	X	X	?	X	-	B	N,O	2.7 L	1,000	0.0027
Sulfate salt (THPS)	55566-30-8	X	X	X	?	?	X	-	B	O	3.6	100	0.036
Compound with urea (THPC-urea)		X	-	-	X	?	X	-	B	D	50	100	0.5
Polymer (THPOH/NH_3)	27104-30-9	?	-	-	-	-	X	-	I				ND
Aromatic phosphates:													
t-Butylphenyl diphenyl phosphate (BPDP)	56803-37-3	-	X	-	-	X	X	X	I				ND
2-Ethylhexyl diphenyl phosphate (EHDP)	1241-94-7	X	X	X	X	X	X	-	B	O	100	100	1.0
Isodecyl diphenyl phosphate (IDDP)	29761-21-5	X	X	-	-	X	X	-	C	O			ND
Phenol isopropylated phosphate (PIP)	68937-41-7	X	X	-	-	X	-	X	C	N,O			ND
Santicizer 141 (>90% EHDP)		X	X	-	X	X	X	-	B	O	100	100	1.0
Santicizer 148 (> 90% IDDP)		X	X	-	X	X	X	-	B	O			0.01
Santicizer 154 (TPP + BPDP)		X	X	-	X	X	X	-	C	N,O			ND
o-Tricresyl phosphate (o-TCP)		X	X	-	X	X	-	X	A	N			ND
Tricresyl phosphate (TCP) mixed isomers	1330-78-5	X	X	X	X	X	X	X	B	R,N,O	50 L	1,000	0.05
Triphenyl phosphate (TPP)	115-86-6	X	X	-	X	X	X	X	C	N,O			ND

[a] Adapted from Bittner et al. 2001.
[b] X indicates availability of data; ? limited data available; -, no data available.
[c] Chronic toxicity as defined under the Federal Hazardous Substances Act and the CPSC chronic hazard guidelines: A, known to be toxic in humans; B, probably toxic in humans; C, possibly toxic in humans; I, insufficient data. Based on oral studies, except where indicated.
[d] Toxic endpoint(s): C, cancer; D, developmental; N, neurotoxic; R, reproductive; O, other (e.g., liver toxicity).
[e] Doses are in mg/kg-d by the oral route, except where indicated. L indicates LOAEL.

References

Albright & Wilson (1998) Letter from Celia Powell, Albright & Wilson, Glen Allen, VA to Dale Ray, U.S. Consumer Product Safety Commission, with attachments. July 17, 1998.

Babich MA, Hatlelid K, Osterhout C (2004) Update on the toxicity of selected flame retardant chemicals—DRAFT. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. July 20, 2004.

Babich MA, Thomas TA (2001) CPSC staff exposure and risk assessment of flame retardant chemicals in residential upholstered furniture. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. April 4, 2001.

Baitinger, W.F. (2000) Personal communication from Dr. Baitinger, Westex, Inc., to Michael Babich, CPSC. November 16, 2000.

Birnbaum LS, Staskal DF (2004) Brominated flame retardants: cause for concern? Environmental Health Perspectives 112: 9-17.

Bittner PM (1999a) Toxicity review for decabromodiphenyl oxide. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (1999b) Toxicity review for phosphonic acid, (3-{[hydroxymethyl]amino}-3-oxopropyl-, dimethyl ester. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (1999c) Toxicity review for tetrakis(hydroxymethyl) phosphonium salts precondensate with urea. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 6, 1999.

Bittner PM (1999d) Toxicity review for tris(2-chloropropyl) phosphate. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (2001) Update on the flame retardant (FR) chemicals toxicity reviews. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. April 4, 2001.

Bittner PM, Ferrante J, Hatlelid KM, Saltzman LE, Babich MA (2001) An evaluation of the toxicity data for selected flame retardant chemicals. The Toxicologist 60: 2014A.

Branchi I, Alleva E, Costa LG (2002) Effects of perinatal exposure to a polybrominated diphenyl ether (PBDE 99) on mouse neurobehavioral development. Neurotoxicology 23: 375-384.

Branchi I, Capone F, Alleva E, Costa LG (2003) Polybrominated diphenyl ethers: neurobehavioral effects following develolpmental exposure. Neurotoxicology 24: 449-462.

Brominated Flame Retardant Industry Panel (BFRIP) (2003) Report of the Peer Consultation Meeting on Decabromodiphenyl Ether. Brominated Flame Retardant Industry Panel, American Chemistry Council. September 30, 2003.

Cobb D (2000) Identification of phosphorus compounds in migration study of immersion treated fabrics. Directorate for Laboratory Sciences, U.S. Consumer Product Safety Commission, Bethesda, MD 20814. December 2000.

Consumer Product Safety Commission (CPSC) (2003) Briefing Package on Cigarette Ignition of Upholstered Furniture: Commission Options. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. July 2003.

Consumer Product Safety Commission (CPSC) (2004) Briefing Package on Notice of Proposed Rulemaking for the Flammability (Open Flame) of Mattresses and Foundations and Options for Addressing Bedclothes Involvement in Mattress/Bedding Fires. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. November 2004.

D'Ruiz C (1998) Testimony presented before the U.S. Consumer Product Safety Commission. May 6, 1998.

Environmental Protection Agency (EPA) Health Effects Test Guidelines—OPPTS 870.6300 Developmental Neurotoxicity Study. Office of Pollution Prevention, Pesticides, and Toxic Substances, U.S. Environmental Protecting Agency, Washington, DC 20460. August 1998. EPA 712-C-98-239.

Eriksson P, Viberg H (2004) Letter to the editor. Response to letter from Vijverberg and van den Berg. Toxicological Sciences 79: 207-208.

Eriksson P, Viberg H, Jakobsson E, Orn U, Fredriksson A (2002) A brominated flame retardant, 2,2',4,4',5-pentabromodiphenyl ether: uptake, retention, and induction of neurobehavioral alterations in mice during a critical phase of neonatal brain development. Toxicological Sciences 67: 98-103.

Ferrante J (1999a) Toxicity review of aromatic phosphate plasticizers. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. June 7, 1999.

Ferrante J (1999b) Toxicity review for tris(1-chloro-2-propyl)phosphate and bis(2-chloropropyl) 1-(chloro-2-propyl) phosphate. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. July 9, 1999.

Frank AW, Daigle D.J; Vail SL (1982a) Chemistry of hydroxymethyl phosphorus compounds. Part II: Phosphonium salts. Textile Research Journal 52: 678-693.

Frank AW, Daigle D.J; Vail SL (1982b) Chemistry of hydroxymethyl phosphorus compounds. Part III: Phosphines, phosphine oxides, and phosphonium hydroxides. Textile Research Journal 52: 738-750.

Fire Retardant Chemicals Association (FRCA) (1998) Letter from Russell C. Kidder, Fire Retardant Chemicals Association, Lancaster, PA to the Office of the Secretary, U.S. Consumer Product Safety Commission, with attachments. August 3, 1998.

Hardy ML (2002) The toxicology of the three commercial polybrominated diphenyl oxide (ether) flame retardants. Chemosphere 46: 757-777.

Hatlelid K (1999) Toxicity review for antimony trioxide. Directorate for Health Sciences, U.S. Consumer Product Safety Commission, Bethesda, MD 20814. March 2, 1999.

Levenson M (2004) Upholstered furniture addressable fire loss estimates for 1995 to 1999. Directorate for Epidemiology. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. March 8, 2004.

Loewengart G, Van Duuren BL (1977) Evaluation of chemical flame retardants for carcinogenic potential. Journal of Toxicology and Environmental Health, 2: 539-546.

MacGregor JT, Diamond MJ, Mazzeno LW Jr., Friedman M (1980) Mutagenicity tests of fabric-finishing agents in Salmonella typhimurium: Fiber-reactive wool dyes and cotton flame retardants. Environmental Mutagenesis, 2: 405-418.

Martin P (1998) Personal communication from Dr. Martin, Albright and Wilson, U.K., to Patricia Bittner, U.S. Consumer Product Safety Commission. November 24, 1998.

Mischutin V (1975) A new FR system for synthetic/cellulosic blends. Textile Chemist and Colorist, Volume 7. March 1975.

National Research Council (NRC) (2000) Toxicological Risks of Selected Flame-Retardant Chemicals. Subcommittee on Flame Retardant Chemicals, National Research Council, National Academy of Sciences. National Academy Press, Washington, DC. ISBN 0-309-07047-3.

National Toxicology Program (NTP) (1986) NTP technical report on the toxicology and carcinogenesis studies of decabromodiphenyl oxide in F344/N rats and B6C3F$_1$ mice (feed studies). NTP TR 309. NIH publications no. 86-2565. U.S. Department of Health and Human Services.

Saltzman LE, Babich MA (1999) Tris(chloropropyl) phosphate (TCPP). U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. August 4, 1999.

Sanders HJ (1978) Flame retardants. Chemical and Engineering News. Pages 22-36, April 24, 1978.

Vail SL, Daigle DJ, Frank AW (1982) Chemistry of hydroxymethyl phosphorus compounds. Part I: Introduction. Textile Research Journal 52: 671-677.

Viberg H, Fredriksson A, Eriksson P (2002) Neonatal exposure to the brominated flame retardant 2,2',4,4',5-pentabromodiphenyl ether causes altered susceptibility in the cholinergic transmitter system in the adult mouse. Toxicological Sciences 67:104-7.

Viberg H, Fredriksson A, Jakobsson E, Örn U, and Eriksson P (2003a) Neurobehavioral derangements in adult mice receiving decabrominated diphenyl ether (PBDE 209) during a defined period of neonatal brain development. Toxicological Sciences 76:112-120.

Viberg H, Fredriksson A, Eriksson P (2003b) Neonatal exposure to polybrominated diphenyl ether (PBDE 153) disrupts spontaneous behaviour, impairs learning and memory, and decreases hippocampal cholinergic receptors in adult mice. Toxicology and Applied Pharmacology 192: 95-106.

Vijverberg HPM, van den Berg M (2004) Letter to the editor. Re: Viberg et al. 2003a. Toxicological Sciences 79: 205-206.

World Health Organization (WHO) (1997) Flame Retardants: A General Introduction. Environmental Health Criteria 192. International Program on Chemical Safety, World Health Organization, Geneva.

World Health Organization (WHO) (2000) Flame Retardants: Tris(2-butoxyethyl) phosphate, tris(2-ethylhexyl) phosphate and tetrakis(hydroxymethyl) phosphonium salts. Environmental Health Criteria 218. International Program on Chemical Safety, World Health Organization, Geneva.

Enclosures

CPSC Staff Toxicity Reviews

Babich MA, Hatlelid K, Osterhout C (2004) Update on the toxicity of selected flame retardant chemicals. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. July 20, 2004.

Bittner PM (1999a) Toxicity review for decabromodiphenyl oxide. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (1999b) Toxicity review for phosphonic acid, (3-{[hydroxymethyl]amino}-3-oxopropyl-, dimethyl ester. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (1999c) Toxicity review for tetrakis(hydroxymethyl) phosphonium salts precondensate with urea. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 6, 1999.

Bittner PM (1999d) Toxicity review for tris(2-chloropropyl) phosphate. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. March 3, 1999.

Bittner PM (2001) Update on the flame retardant (FR) chemicals toxicity reviews. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. April 4, 2001.

Bittner PM, Ferrante J, Hatlelid KM, Saltzman LE, Babich MA (2001) An evaluation of the toxicity data for selected flame retardant chemicals. The Toxicologist 60: 2014A.

Ferrante J (1999a) Toxicity review of aromatic phosphate plasticizers. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. June 7, 1999.

Ferrante J (1999b) Toxicity review for tris(1-chloro-2-propyl)phosphate and bis(2-chloropropyl) 1-(chloro-2-propyl) phosphate. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. July 9, 1999.

Hatlelid K (1999) Toxicity review for antimony trioxide. Directorate for Health Sciences, U.S. Consumer Product Safety Commission, Bethesda, MD 20814. March 2, 1999.

Saltzman LE, Babich MA (1999) Tris(chloropropyl) phosphate (TCPP). U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. August 4, 1999.

CPSC Staff Risk Assessment

Babich MA, Thomas TA (2001) CPSC staff exposure and risk assessment of flame retardant chemicals in residential upholstered furniture. U.S. Consumer Product Safety Commission, Directorate for Health Sciences, Bethesda, MD 20814. April 4, 2001.

Cobb D (2000) Identification of phosphorus compounds in migration study of immersion treated fabrics. Directorate for Laboratory Sciences, U.S. Consumer Product Safety Commission, Bethesda, MD 20814. December 2000.

National Research Council Report

National Research Council (NRC) (2000) Toxicological Risks of Selected Flame-Retardant Chemicals. Subcommittee on Flame Retardant Chemicals, National Research Council, National Academy of Sciences. National Academy Press, Washington, DC. ISBN 0-309-07047-3.