

1992). Ambient AT levels in the U.S. range from 0.00045 to 171 ng/m<sup>3</sup>, with higher levels in urban areas (ibid.). The sources of ambient AT include refuse incineration and automobile exhaust.

The exposure estimate for AT particles differs somewhat from the NRC report. NRC estimated a HI of 1.2 and a cancer risk of  $1.7 \times 10^{-4}$  for inhalation exposure to particles containing AT (NRC, 2000, p. 8). The difference between the two risk assessments is due to differences in assumptions for room size and air infiltration rate, as well as inhalation ADI (discussed above). Both risk assessments used essentially similar assumptions to estimate the particle emission rate. However, both exposure assessments are based entirely on assumptions and models. This issue could be resolved by obtaining empirical data from field or laboratory studies.

It should be noted that the CPSC inhalation "ADI" value (0.009 µg/m<sup>3</sup>) is considerably lower than the RfC value used by NRC (0.2 µg/m<sup>3</sup>) and EPA (reviewed in Hatlelid, 1999a). The reasons for this difference are discussed above (Comparison with the NRC Report) and in the CPSC toxicity review (Hatlelid, 1999a).

It should also be noted that there is some controversy in the scientific community regarding the significance of the lung tumors induced in rats by AT (discussed in Hatlelid, 1999a). AT caused lung tumors in two of three studies (Groth et al., 1986; Newton et al., 1994; Watt, 1983). Inert particles such as carbon black or titanium dioxide have been shown to induce tumors in rats, but not other species. This issue could be resolved by obtaining data in another species. However, if data were obtained showing that exposure is actually less than the predicted level, this would become a moot point. In addition, the lung tumors in animals and the non-cancer effects observed in the animals and in workers were from exposure to AT in the form of mineral dusts. The AT typically used in back-coatings has particles ranging from 1 to 3 µm in diameter (Long, 2001), which includes the respirable range (<2.5 µm). However, AT in particles from treated fabrics would be encapsulated in an organic matrix containing fabric fibers and back-coating or binder. It is unknown how this matrix might affect the bioavailability of AT and the resulting risk. Finally, the cancer risks predicted by CPSC and the NRC are based on the assumption that cancer risk is a linear function of dose. Given that AT is a mineral dust and that it is non-genotoxic, it is conceivable that a non-linear (threshold) mechanism could apply, which would result in an even lower risk to consumers.

**DBDPO and HBCD.** DBDPO and HBCD are not likely to present a hazard to consumers. This is essentially similar to the conclusions reached by the NRC Subcommittee (NRC, 2000). In all cases, the HI was less than one. For DBDPO, the HI for the basic case was only 0.008 in adults and children, even with very conservative dermal exposure assumptions (Table III-3). For HBCD, the HI for the basic case was 0.007 in adults and 0.02 in children (Table III-4). Thus, even if the total exposure were underestimated by 50- to 100-fold, exposure would still be at or below the ADI and RfD values, respectively. Although, the HI values were greater for the non-aqueous cleaner case (0.07 for DBDPO and 0.37 for HBCD) the exposure assumptions were sufficiently conservative that HI is not likely to be exceeded under reasonably foreseeable conditions. Furthermore, the CPSC staff believes that many of the upholstery cleaning products used by consumers and at least some products used by professionals are water-based (Bhooshan and Cobb, 2000; Tao et al., 2000).

HBCD does not satisfy the FHSA definition of toxic and, therefore, is not hazardous under the FHSA. However, a risk assessment for HBCD was performed using the RfD calculated by NRC.

PA. PA does not satisfy the FHSA definition of “toxic” and, therefore, it cannot be considered “hazardous.” This is essentially similar to the conclusion reached by the NRC Subcommittee (NRC, 2000). Although there is no evidence demonstrating toxic effects of PA, the database is limited. The most extensive study of PA is a 21-day study which did not include microscopic examination of all the major organs (reviewed in Bittner, 1999b). Because PA is not classified as “toxic,” an exposure assessment was not needed to determine whether it may be hazardous, but migration data were available. If additional toxicity data become available in the future and an ADI or RfD is derived, then they may be applied to the estimated exposures presented above. It should be noted that PA reacts with cellulosic fibers and durable press resins. The precise chemical form of the phosphorus compounds found in extracts of PA-treated fabrics is unknown.

The CPSC staff noted that the extent of migration from PA-treated fabric was relatively high, approximately 7 percent of total phosphorus was lost when the fabric was exposed to saline or detergent, using the filter paper method to measure migration (Table II-3a) (Bhooshan and Cobb, 2000). LSC performed five serial extractions on the same fabric sample. The report gives the total migration for the five consecutive extractions on the same fabric sample. However, an examination of the raw data reveals that the rate of loss declines rapidly following the first extraction. This suggests that these reaction by-products could be removed by a wash step following the chemical treatment, which would reduce the potential for exposure. It also suggests that the estimated exposure levels would not be maintained over the life of the product.

THPC. The potential risks from exposure to THPC-treated fabrics could not be assessed. THPC is a reactive compound that polymerizes and then undergoes a subsequent oxidation step. Migration studies revealed the presence of a significant amount of phosphorus-containing compounds in extracts of treated fabric, but no THPC was detected (Cobb, 2000). The phosphorus-containing compounds could not be identified, but it has been suggested that they are THPO and polymers or oligomers of THPO (Baitinger, 2000; Martin, 1998). No toxicity data on THPO were available, except that it is not mutagenic in *Salmonella* (MacGregor et al., 1980). Polymers and oligomers would likely present less of a hazard, because they would be poorly absorbed. Thus, the potential risks from exposure to THPC-treated fabrics could not be assessed without additional information on the migrating species. However, if the compounds in the extracts were as toxic as THPC, then THPC-treated fabrics would likely present a hazard to consumers, as the predicted ADD's (0.09 to 0.17 mg/kg-d) were greater than the ADI for THPC (0.0027 mg/kg-d). Clearly, additional information about the composition and the toxicity of the compounds present is needed to determine whether THPC-treated fabrics may present a hazard to consumers.

The NRC Subcommittee concluded that THPC would present a minimal risk to consumers. However, migration data for THPC-treated fabrics were not available when the Subcommittee completed its report. The Subcommittee reasonably concluded that THPC would be

incorporated into a polymer and that percutaneous absorption of any residual THPC would be negligible. However, the migration data reported by LSC (Bhooshan and Cobb, 2000) suggest that a significant amount of unidentified phosphorus compounds are released into aqueous media. Both the NRC and other authors recommended that additional information on the identity and toxicity of the compounds released from THPC-treated fabrics are needed (Loewengart and Van Duuren, 1977; NRC, 2000, p. 436).

As with PA, the extent of migration from THPC-treated fabric was relatively high, approximately 3 percent of total phosphorus was lost when the fabric was exposed to saline or detergent, using the filter paper method to measure migration (Table II-3a) (Bhooshan and Cobb, 2000). LSC performed five serial extractions on the same fabric sample. The report gives the total migration for the five consecutive extractions on the same fabric sample. However, an examination of the raw data reveals that the rate of loss declines rapidly following the first extraction. This suggests that these reaction by-products could be removed by a wash step following the chemical treatment, which would obviate any concerns about possible toxicity. It also suggests that the estimated exposure levels would not be maintained over the life of the product. In comparison, roughly 20 percent of total phosphorus or total nitrogen was lost from apparel fabrics during the course of 40 to 50 consecutive launderings at high temperature (Albright and Wilson, 1998c). Typically the phosphorus content declined from about 2.5 % to 2.0 % over the course of 40 to 50 washes (Albright and Wilson, 1998c). Most of the loss occurred during the first ten launderings.

Risk assessments were also performed for three chemicals for which migration data were not available. Exposure data need to be obtained to support the following conclusions.

CPE. It appears that CPE would not present a hazard, even if residual CPE were not removed by washing. The HI value was 0.001 for washed fabric and 0.025 for unwashed fabric. While migration data are needed to confirm these conclusions, the low HI's suggest that a different conclusion is unlikely. The actual total exposure would have to be 40-fold to 1,000-fold greater than estimated for CPE to be hazardous. The NRC Subcommittee did not perform a risk assessment for CPE. Instead, the NRC performed a risk assessment for methyl phosphonate, which is the most toxic representative of the organic phosphonate class.

EHDP. EHDP would probably not present a hazard to consumers. EHDP exposure is not likely to exceed the ADI unless the fabric is exposed to non-aqueous cleaners (dry cleaning fluid). The CPSC staff believes that many of the upholstery cleaning products used by consumers and at least some products used by professionals are water-based (Bhooshan and Cobb, 2000; Tao et al., 2000). In all other cases, the ADI is less than one. Therefore, the staff concludes that EHDP would probably not present a hazard to consumers. Migration data are needed to confirm these conclusions. Furthermore, these conclusions do not necessarily apply to other members of the aromatic phosphate ester class. For example, tricresyl phosphate isomeric mixture has a considerably lower ADI (i.e., it is more toxic) than EHDP (Table I-2). The NRC Subcommittee did not perform a risk assessment for EHDP.

TDCP. It appears that TDCP could present a hazard to consumers, based on both cancer and non-cancer risks. Although dermal exposure was the primary route of exposure, both

inhalation of vapor phase TDCP and oral exposure contributed significantly to the total exposure. These exposure estimates could be confirmed by conducting studies to estimate dermal, oral, and inhalation exposure. Furthermore, the cancer potency estimate and RfD were based on an oral study. Thus, it was assumed that the absorption of inhaled TDCP is as efficient as absorption by the oral route. Information on the toxicokinetics of TDCP or inhalation bioassay data would also reduce the uncertainty associated with route-to-route extrapolation. While additional data are needed to support the conclusions presented here, the magnitude of the cancer risk estimates (about 300 per million) indicate that the true exposure would need to be 300-fold lower than estimated, if TDCP is to be used in upholstered furniture.

The overall conclusion regarding TDCP essentially is similar to the conclusion reached by the NRC Subcommittee (NRC, 2000). However, the NRC found greater risks for oral exposure and lower risks for dermal exposure. Both CPSC and NRC concluded that exposure studies relating to all three potential routes of exposure are needed (NRC, 2000, p. 384).

## **2. Effect of Age, Wear, and Cleaning**

LSC studied the effect of age and wear on the migration of FR chemicals from treated fabrics (Bhooshan and Cobb, 2000; Levenson, 2000). Fabrics were subjected to an accelerated aging process or an accelerated mechanical wear process, and then the migration tests were repeated. This process included exposure to UV and elevated temperatures. The UV exposure was equivalent to 5,000 hours of indoor UV exposure. On average, migration rates observed with the artificially aged or worn fabrics were double the migration rates with the new fabrics. However, this was not sufficient to affect the conclusions regarding whether a given FR treatment could present a hazard.

Some treatments significantly increased the migration of FR chemicals. For example, AT migration was considerably greater with citric acid than with saline, which is expected since AT is soluble in weak acid. This observation is relevant, because some beverages and foods (for example, cola) are acidic. Extraction of AT-treated fabric with citric acid increased the HI to 0.33. A change in any other parameter, such as increased migration rate with age, could bring the HI very close to one. However, this scenario assumes that the entire fabric surface was exposed to an acidic solution, which is unlikely to occur. In addition, the percutaneous absorption rate of AT is unknown; a default value was assumed. While it is possible that the actual rate is greater, the absorption rates of inorganic compounds are generally very low or even negligible.

Non-aqueous cleaner (that is, methyl chloroform) significantly increased the migration of DBDPO and HBCD. With both chemicals, this results in HI values close to one. However, the CPSC staff believes that most upholstery cleaning products used by consumers and professionals are water-based.

### **D. Recommendations**

Manufacturers and distributors are responsible for ensuring that their products do not present a hazard to consumers as defined by the FHSA, or, if they do present a hazard, that they

are properly labeled in accordance with the FHSA. If the draft open flame standard is adopted, manufacturers of FR chemicals, FR chemical applicators, fabric finishers, and furniture manufacturers need to ensure that the FR treatments used do not present a hazard to consumers. This risk assessment describes one approach that could be used to estimate exposure and risk from FR treatments. A number of FR treatments are available that appear to satisfy the requirements of the FHSA, including CPE, DBDPO, HBCD, PA, and probably EHDP. However, the conclusions in this report would not necessarily apply to all products containing these chemicals. The migration rates were based on a limited number of fabric samples, some of the fabric samples tested were pre-production samples, and differences in fabric types, fabric weights, FR application rates, or back-coating formulations could affect exposure.

Table IV-1. Conclusions for individual FR chemicals.

FR chemical	"Toxic" under the FHSA <sup>a</sup>	Migration data available <sup>b</sup>	Percutaneous absorption data available <sup>c</sup>	"Hazardous" under the FHSA <sup>d</sup>
Antimony trioxide (AT)	Yes	Yes	No	Possibly <sup>e</sup>
Cyclic phosphonate ester (CPE)	Yes	No	Yes	No
Decabromodiphenyl oxide (DBDPO)	Yes	Yes	Yes	No
2-Ethylhexyl diphenyl phosphate (EHDP)	Yes	No	No	Probably not <sup>f</sup>
Hexabromocyclododecane (HBCD)	No	Yes	Yes	No
Phosphonic acid, (3-[(hydroxymethylamino)-3-oxopropyl]-, dimethyl ester (PA))	No	Yes	No	No
Tetrakis (hydroxymethyl) phosphonium chloride (THPC)	Yes	Yes	No	Insufficient data <sup>g</sup>
Tris (1,3-dichloropropyl-2) phosphate (TDCP)	Yes	No	Yes	Probably <sup>h</sup>

<sup>a</sup> Satisfies the Federal Hazardous Substances Act (FHSA) definition of "toxic."

<sup>b</sup> Whether migration (leaching) data were available to assess liquid-mediated dermal exposure.

<sup>c</sup> Whether percutaneous absorption data were available.

<sup>d</sup> A substance is "hazardous" under the FHSA if the hazard index is greater than one or the individual lifetime excess cancer risk is greater than one-in-a million during reasonably foreseeable handling or use.

<sup>e</sup> Exposure to airborne particle-bound AT is estimated to be at or near the acceptable levels for non-cancer effects and cancer. Additional data on inhalation exposure are needed to determine whether AT may present a hazard by inhalation.

<sup>f</sup> EHDP may possibly present a hazard if the treated fabric is exposed to non-aqueous cleaners. A surrogate compound (HBCD) was used to estimate dermal exposure. Migration data are needed to confirm these conclusions.

<sup>g</sup> THPC is a reactive chemical. The principal chemical species migrating from the treated fabric could not be identified. Additional information on the identity and toxicity of the migrating species are needed.

<sup>h</sup> A surrogate compound (HBCD) was used to estimate dermal exposure. Data on liquid-mediated migration and the emission of vapor phase TDCP are needed to confirm this conclusion.

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## APPENDIX

### Derivation of Equations

This Appendix describes the derivation of the equations used to predict exposure to FR chemicals in upholstered furniture fabrics and the resulting dose and risk.

#### I. Exposure and Dose

##### A. Dermal Exposure (Scenarios D.1, D.2, and D.3)\*

It will be assumed that an external liquid phase facilitates the transfer of FR chemical from the fabric to the skin (NRC, 2000, p. 38). Depending on the circumstances, the liquid phase may be perspiration, other body fluids, spilled beverages, or liquid cleaners. The dermal exposure process may be described by:

$$FR_{Fabric} \longrightarrow FR_{Liquid} \longrightarrow FR_{Skin} \longrightarrow FR_{Absorbed} \quad (A.1)$$

where:  $FR_{Fabric}$ , FR chemical in the fabric;  $FR_{Liquid}$ , FR chemical in the liquid phase (e.g., perspiration);  $FR_{Skin}$ , FR chemical in contact with the skin; and  $FR_{Absorbed}$ , FR chemical that is absorbed through the skin.

The effective concentration of FR chemical on the skin,  $C_S$ , is given by:

$$C_S = L \cdot M_L \quad (A.2)$$

where:  $C_S$ , specific concentration<sup>†</sup> of FR chemical on the skin,  $\text{mg}/\text{cm}^2$ ;  $L$ , FR chemical loading,  $\text{mg}/\text{cm}^2$ ; and  $M_L$ , fraction of FR chemical that migrates into the liquid phase.

In some cases, such as cleaning up spilled beverages, the liquid phase may be dried with a towel. When this occurs, a fraction of the liquid phase ( $F_F$ ) will remain in the fabric. Thus, equation (A.2) may be modified as follows:

$$C_S = L \cdot M_L \cdot F_F \quad (A.3)$$

where:  $C_S$ , specific concentration of FR chemical on the skin,  $\text{mg}/\text{cm}^2$ ;  $L$ , FR chemical loading,  $\text{mg}/\text{cm}^2$ ;  $M_L$ , fraction of FR chemical that migrates into the liquid phase; and  $F_F$ , fraction of the liquid phase remaining in the fabric after the bulk liquid is removed, unitless.

The amount of FR chemical absorbed through the skin, that is, the dermal dose is:

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\* The scenario designations are described in Table 2 in section I.D, Scope of the Risk Assessment.

† Specific concentration is the amount of chemical per unit area.

$$D = C_S \cdot A_S \cdot k_T \cdot T \quad (\text{A.4})$$

where:  $C_S$ , as defined above;  $D$ , dermal dose, mg;  $A_S$ , surface area of exposed skin,  $\text{cm}^2$ ;  $k_T$ , percutaneous absorption rate, i.e., dermal transfer coefficient (Scheuplein and Ross, 1974),  $\text{h}^{-1}$ ; and  $T$ , duration of exposure, h.

Substituting equation (A.3) into equation (A.4) gives:

$$D = L \cdot M_L \cdot F_F \cdot A_S \cdot k_T \cdot T \quad (\text{A.5})$$

The average daily dose ADD is given by:

$$ADD = \frac{D \cdot N}{W} \quad (\text{A.6})$$

where:  $N$ , the number of exposures per day,  $\text{d}^{-1}$ ; and  $W$ , body weight, kg.

Substituting equation (A.5) into equation (A.6) gives:

$$ADD_{D,x} = \frac{L \cdot M_L \cdot F_F \cdot A_S \cdot k_T \cdot T \cdot N}{W} \quad (\text{A.7})$$

where:  $ADD_{D,x}$ , average daily dose from scenario  $D,x$ ,  $\text{mg}/\text{kg}\cdot\text{d}$ ;  $L$ , FR chemical loading,  $\text{mg}/\text{cm}^2$ ;  $M_L$ , fraction of unbound FR that migrates into the liquid phase;  $F_F$ , fraction of liquid phase remaining in the fabric after the bulk liquid is removed, unitless;  $A_S$ , skin surface area exposed,  $\text{cm}^2$ ;  $k_T$ , percutaneous absorption rate,  $\text{h}^{-1}$ ;  $T$ , exposure duration, h;  $N$ , number of exposures per day,  $\text{d}^{-1}$ ; and  $W$ , body weight, kg.

## B. Oral Exposure--Children's Mouthing Activity (O.1)

Small children may mouth a variety of objects for brief periods of time (Smith and Kiss, 1998), including portions of upholstered furniture, such as the cushions or arm covers. The migration rate of FR chemicals into a saliva simulant may be measured by an appropriate laboratory method, such as the head-over-heels method. The oral dose is estimated by:

$$D = k_H \cdot A_F \cdot T \quad (\text{A.8})$$

where:  $D$ , oral dose, mg;  $k_H$ , migration rate,  $\text{mg}/\text{cm}^2/\text{h}$ , as measured by the head-over-heels method (Bhooshan and Cobb, 2000);  $A_F$ , fabric area,  $\text{cm}^2$ ; and  $T$ , exposure duration, hours.

The average daily dose, ADD, is given by equation (A.6):

$$ADD = \frac{D \cdot N}{W} \quad (\text{A.9})$$

where: N, number of exposures per day,  $d^{-1}$ ; and W, body weight, kg.

Substituting equation (A.8) into equation (A.9):

$$ADD_{O.1} = \frac{k_H \cdot A_F \cdot T \cdot N}{W} \quad (\text{A.10})$$

where:  $ADD_{O.1}$ , average daily dose from scenario O.1, mg/kg-d;  $k_H$ , migration rate,  $mg/cm^2 \cdot h$ , as measured by the head-over-heels methods (Bhooshan and Cobb, 2000);  $A_F$ , fabric area,  $cm^2$ ; T, exposure duration, h; N, number of exposures per day,  $d^{-1}$ ; and W, body weight, kg.

### C. Inhalation

Consumers may be exposed to FR chemicals in the form of vapors and particles released from fabric fibers.

#### 1. Semi-volatile FR Chemicals (I.1)

Inhalation exposure may occur from the emission of semi-volatile FR chemicals into indoor air. The extent of exposure by this route may be predicted as follows.

A simple one-zone mass balance model may be used to predict the concentration of FR chemicals in indoor air (NRC, 1981). The steady-state pollutant concentration in indoor air is given by:

$$C_A = \frac{S}{ACH \cdot V} \quad (\text{A.11})$$

where:  $C_A$ , concentration in indoor air,  $mg/m^3$ ; S, source strength, mg/h; ACH, air infiltration rate,  $h^{-1}$ ; V, room volume,  $m^3$ .

This equation does not correct for sink effects. Other materials in the home, such as carpet, draperies, or wallboard, may absorb semi-volatile FR chemicals in the air. This tends to reduce the concentrations in air. Sink effects are not included, because relevant data are not available.

The average daily dose (ADD) is given by:

$$ADD = \frac{C_A \cdot I \cdot T \cdot N}{W} \quad (\text{A.12})$$

where: ADD, average daily dose, mg/kg-d;  $C_A$ , average concentration in air, mg/m<sup>3</sup>; I, average inhalation rate, m<sup>3</sup>/h; T, exposure duration, h; N, number of exposures per day, d<sup>-1</sup>; and W, body weight, kg.

Substituting equation (A.11) into equation (A.12) gives:

$$ADD_{I.1} = \frac{S \cdot I \cdot T \cdot N}{ACH \cdot V \cdot W} \quad (\text{A.13})$$

where:  $ADD_{I.1}$ , average daily dose from exposure scenario I.1, mg/kg-d; S, source strength, mg/h; I, average inhalation rate, m<sup>3</sup>/h; T, exposure duration, h; N, number of exposures per day, d<sup>-1</sup>; ACH, air infiltration rate, h<sup>-1</sup>; V, room volume, m<sup>3</sup> and W, body weight, kg.

In some cases, such as an airborne pollutant that acts directly on the respiratory tract, it may be convenient to estimate the hazard index or cancer risk from the average concentration in air (CPSC, 1992). In this case, the average daily exposure (ADE) may be calculated by:

$$ADE = \frac{C_A \cdot T \cdot N}{24} \quad (\text{A.14})$$

where: ADE, time-weighted average daily exposure, mg/m<sup>3</sup>;  $C_A$ , airborne FR concentration, mg/m<sup>3</sup>; T, exposure duration, h; N, number of exposures per day, d<sup>-1</sup>; and 24, the number of hours per day.

Substituting equation (A.11) into equation (A.14) gives:

$$ADE_{I.1} = \frac{S \cdot T \cdot N}{ACH \cdot V \cdot 24} \quad (\text{A.15})$$

where:  $ADE_{I.1}$ , time-weighted average daily exposure from scenario I.1, mg/m<sup>3</sup>; S, source strength, mg/h; ACH, air infiltration rate, h<sup>-1</sup>; V, room volume, m<sup>3</sup>; N, number of exposures per day, d<sup>-1</sup>; T, exposure duration, h; and 24, the number of hours per day.

The source strengths (mass emitted per unit time) of volatile chemical emissions from building or furnishing materials are typically derived from emission rates (source strength per unit area) measured in small chambers. However, such data are not available for FR chemical-treated fabrics. Therefore, emission rates will be predicted by the use of a mathematical model, described by the National Research Council (NRC, 2000, p. 45). The model predicts the indoor air concentration  $C_A$ :

$$C_A = C_{Sat} \frac{\lambda \cdot \eta + \gamma}{1 + \eta} \quad (\text{A.16})$$

where:

$$\lambda = \frac{C_0}{C_{Sat}} \quad (\text{A.17})$$

$$\eta = \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}} \quad (\text{A.18})$$

and where:  $C_A$ , concentration of FR chemical in air,  $\text{mg}/\text{m}^3$ ;  $C_{Sat}$ , saturation concentration of the FR chemical in air,  $\text{mg}/\text{m}^3$ ;  $C_0$ , ambient FR chemical concentration  $\text{mg}/\text{m}^3$ ;  $\lambda$ , ratio of  $C_0$  to  $C_{sat}$ , unitless;  $\eta$ , defined by equation (A.18);  $\gamma$ , dimensionless factor from 0 to 1 to account for sink effects, where 1 implies no binding to sinks; ACH, air infiltration rate,  $\text{h}^{-1}$ ; V, room volume,  $\text{m}^3$ ; H, boundary layer thickness, that is, layer of air immediately over the fabric where transfer from the solid phase to vapor phase occurs, m;  $F_A$ , fraction of fabric that is exposed to air, unitless;  $A_F$ , fabric area,  $\text{m}^2$ ; and  $D_{Air}$ , diffusivity of the FR chemical in air,  $\text{m}^2/\text{h}$ .

If we assume that  $C_0$  is zero and ignore sink effects, then  $\lambda=0$  and  $\gamma=1$  (NRC, 2000, p. 45). Thus, equation (A.16) becomes:

$$C_A = \frac{C_{Sat}}{1 + \eta} \quad (\text{A.19})$$

Substituting equation (A.18) into equation (A.19) gives:

$$C_A = \frac{C_{Sat}}{1 + \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}}} \quad (\text{A.20})$$

Substituting  $(ACH \cdot V)/(ACH \cdot V)$  for 1:

$$C_A = \frac{C_{Sat}}{\frac{ACH \cdot V}{ACH \cdot V} + \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}}} \quad (\text{A.21})$$

Factoring:

$$C_A = \frac{1}{ACH \cdot V} \left( \frac{C_{Sat}}{\frac{1}{ACH \cdot V} + \frac{H}{F_A \cdot A_F \cdot D_{Air}}} \right) \quad (A.22)$$

This may be written in the form of equation (A.11), above:

$$C_A = \frac{S}{ACH \cdot V} \quad (A.23)$$

where the source strength for vapor phase FR chemical  $S_V$  is given by:

$$S_V = \frac{C_{Sat}}{\frac{1}{ACH \cdot V} + \frac{H}{F_A \cdot A_F \cdot D_{Air}}} \quad (A.24)$$

The amount of FR chemical on the fabric is finite. Therefore, for a volatile chemical, the amount of FR chemical available for vaporization could, in principle, be exhausted over the lifetime of the furniture. The maximum time that  $C_A$ , as estimated by equation (A.20) could be maintained is given by (NRC, 2000, p. 46):

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \left( \frac{1 + \eta}{\eta \cdot (\gamma - \lambda)} \right) \quad (A.25)$$

where:  $T_{max}$ , maximum time that the steady-state FR concentration in air could be maintained, h; and the other parameters are as defined previously.

If we let  $\lambda=0$  and  $\gamma=1$ , as above, then:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \left( \frac{1 + \eta}{\eta} \right) \quad (A.26)$$

Substituting equation (A.18) into equation (A.26): gives:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \left( 1 + \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}} \right) \quad (A.27)$$

This equation may be simplified as follows. Inverting the denominator in the parentheses gives:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \left( 1 + \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}} \right) \left( \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} \right) \quad (A.28)$$

Multiplying gives:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \cdot \left[ \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} + \left( \frac{ACH \cdot V \cdot H}{F_A \cdot A_F \cdot D_{Air}} \cdot \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} \right) \right] \quad (A.29)$$

Canceling gives:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air}} \left( 1 + \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} \right) \quad (A.30)$$

Coverting  $T_{Max}$  from hours to years:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{8,766 \cdot C_{Sat} \cdot D_{Air}} \left( 1 + \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} \right) \quad (A.31)$$

where: 8,766 is the number of hours per year.

Therefore, the source strength for vapor phase FR chemical may be calculated by:

$$S_V = \frac{C_{Sat}}{\frac{1}{ACH \cdot V} + \frac{H}{F_A \cdot A_F \cdot D_{Air}}} \quad \text{For } T_{Max} \geq Y_F \text{ years} \quad (A.32)$$

$$S_V = \left( \frac{T_{Max}}{Y_F} \right) \left( \frac{C_{Sat}}{\frac{1}{ACH \cdot V} + \frac{H}{F_A \cdot A_F \cdot D_{Air}}} \right) \quad \text{For } T_{Max} < Y_F \text{ years}$$

where:

$$T_{Max} = \frac{10,000 \cdot L \cdot H}{C_{Sat} \cdot D_{Air} \cdot 8,766} \left( 1 + \frac{F_A \cdot A_F \cdot D_{Air}}{ACH \cdot V \cdot H} \right) \quad (A.33)$$

and where:  $S_V$ , source strength for vapor phase FR chemical, mg/h;  $C_{Sat}$ , saturation concentration of the FR chemical in air, mg/m<sup>3</sup>; ACH, air infiltration rate, h<sup>-1</sup>; V, room volume, m<sup>3</sup>; H, boundary layer thickness, that is, layer of air immediately over the fabric where transfer from the solid phase to vapor phase occurs, m;  $F_A$ , fraction of fabric that is exposed to air, unitless;  $A_F$ , fabric area, m<sup>2</sup>; and  $D_{Air}$ , diffusivity of the FR chemical in air, m<sup>2</sup>/h;  $T_{max}$ , maximum time that the steady-state FR concentration in air could be

maintained, years; L, FR chemical loading, mg/cm<sup>2</sup>; 10,000 is to convert from mg/cm<sup>2</sup> to mg/m<sup>2</sup>; and Y<sub>F</sub>, average lifetime of upholstered furniture, years.

Equation (2.7) may be used in conjunction with equations (2.6) or (A.15) above to calculate the inhalation exposure from semi-volatile FR chemicals. It is important to note that equation (2.7) requires the diffusivity D<sub>Air</sub> to be in units of m<sup>2</sup> per **hour**. Diffusion constants are frequently reported as m<sup>2</sup> per **second**. In addition, for convenience, T<sub>Max</sub> has been converted to **years**, whereas time generally has been expressed in **hours**. Finally, the lengths, areas, and volumes used in estimating inhalation exposure are generally in **meters**, whereas **centimeters** are used in most other cases. Therefore, appropriate care should be taken to use the proper units.

## 2. Particles (I.2)

Upholstered furniture fabrics may release particles containing FR chemicals into the air during use. Many of these particles are likely to be larger than respirable size (>2.5 μm in diameter). Nonetheless, some particles may be of respirable size.

The average daily dose (ADD) is given by:

$$ADD = \frac{C_{AP} \cdot I \cdot T \cdot N}{W} \quad (A.34)$$

which is essentially similar to equation (A.12), and where: ADD, average daily dose, mg/kg-d; C<sub>AP</sub>, average concentration of particle-bound FR chemical in air, mg/m<sup>3</sup>; I, average inhalation rate, m<sup>3</sup>/h; T, exposure duration, h; N, number of exposures per day, d<sup>-1</sup>; and W, body weight, kg.

If direct measurements of particle-bound FR chemical in indoor air, C<sub>AP</sub>, are available, equations (A.34) and (2.11) may be used to estimate exposure. In the absence such data, a simple one-zone mass balance model may be used to predict the C<sub>AP</sub>. This is essentially similar to equation (A.11), except that a decay rate for the deposition of particles is included. The steady-state particle-bound concentration in indoor air C<sub>AP</sub> is given by:

$$C_{AP} = \frac{S_P}{V(ACH + k_D)} \quad (A.35)$$

where: C<sub>AP</sub>, concentration of particle-bound FR chemical in indoor air, mg/m<sup>3</sup>; S<sub>P</sub>, source strength of particle-bound FR chemical, mg/h; V, room volume, m<sup>3</sup>; ACH, air infiltration rate, h<sup>-1</sup>; and k<sub>D</sub>, particle deposition rate, h<sup>-1</sup>.

Substituting equation (2.5) into equation (A.34) gives:

$$ADD_{12} = \frac{S_P \cdot I \cdot T \cdot N}{W \cdot V(ACH + k_D)} \quad (A.36)$$

where:  $ADD_{I,2}$ , average daily dose from scenario I.2, mg/kg-d;  $S_p$ , source strength of particle-bound FR chemical, mg/h;  $I$ , average inhalation rate, m<sup>3</sup>/h;  $T$ , exposure duration, h;  $N$ , number of exposures per day, d<sup>-1</sup>;  $W$ , body weight, kg;  $V$ , room volume, m<sup>3</sup>;  $ACH$ , air infiltration rate, h<sup>-1</sup>; and  $k_D$ , particle deposition rate, h<sup>-1</sup>.

In cases where an airborne pollutant acts directly on the respiratory tract, the average daily exposure (ADE) may be calculated by:

$$ADE = \frac{C_{AP} \cdot T \cdot N}{24} \quad (A.37)$$

where: ADE, time-weighted average daily exposure, mg/m<sup>3</sup>;  $C_{AP}$ , airborne particle-bound FR concentration, mg/m<sup>3</sup>;  $T$ , exposure duration, h;  $N$ , number of exposures per day, d<sup>-1</sup>; and 24, the number of hours per day.

Substituting equation (2.5) into equation (2.11):

$$ADE_{I,2} = \frac{S_p \cdot T \cdot N}{24 \cdot V(ACH + k_D)} \quad (A.38)$$

where:  $ADE_{I,2}$ , time-weighted average daily exposure from scenario I.2, mg/m<sup>3</sup>;  $S_p$ , source strength of particle-bound FR chemical, mg/h;  $T$ , exposure duration, h;  $N$ , number of exposures per day, d<sup>-1</sup>; 24, the number of hours per day;  $V$ , room volume, m<sup>3</sup>;  $ACH$ , air infiltration rate, h<sup>-1</sup>; and  $k_D$ , particle deposition rate, h<sup>-1</sup>.

The source strength,  $S_p$ , can be estimated by:

$$S_p = 10,000 \cdot L \cdot A_F \cdot F_W \cdot k_R \quad (A.39)$$

where: 10,000 cm<sup>2</sup>/m<sup>2</sup> is to convert from mg/cm<sup>2</sup> to mg/m<sup>2</sup>;  $L$ , FR chemical load, mg/cm<sup>2</sup>;  $A_F$ , fabric area, m<sup>2</sup>;  $F_W$ , fraction of the fabric area subjected to heavy wear; and  $k_R$ , fabric particle release rate, h<sup>-1</sup>.

## II. Risk Assessment

### A. Non-Cancer Endpoints

Non-cancer endpoints are evaluated by an uncertainty factor approach (CPSC, 1992, section VI.F.4.b.1.ii, p. 46656). Generally, the no observed adverse effect level (NOAEL) is divided by appropriate uncertainty factors to calculate the acceptable daily intake (ADI). The default uncertainty factors include a factor of 10 for animal to human extrapolation and a factor of 10 for interindividual differences in susceptibility, in other words, to protect susceptible populations. This results in a net uncertainty factor of 100. If a NOAEL has not been established, the lowest observed adverse effect level (LOAEL) is used, and an additional 10-fold uncertainty factor is applied. Thus:

$$ADI = \frac{NOAEL}{UF_H \cdot UF_S}$$

Or

$$ADI = \frac{LOAEL}{UF_H \cdot UF_S \cdot UF_L}$$

where: ADI, acceptable daily intake, mg/kg-d; NOAEL, no-observed-adverse-effect level, mg/kg-d; LOAEL, lowest-observed-adverse-effect level, mg/kg-d;  $UF_H$ , animal to human uncertainty factor;  $UF_S$ , uncertainty factor to protect sensitive populations; and  $UF_L$ , LOAEL to NOAEL uncertainty factor. The uncertainty factors are unitless.

The hazard index (HI) is the ratio of the ADD to the acceptable daily intake (ADI), that is:

$$HI_i = \frac{ADD_i}{ADI}$$

where:  $HI_i$ , hazard index from exposure scenario i, unitless;  $ADD_i$ , average daily dose for exposure scenario i, mg/kg-d; and ADI, acceptable daily intake, mg/kg-d.

When the HI is greater than one, the product or exposure scenario under consideration is considered to present a hazard to consumers. Dermal exposure estimates include an adjustment for bioavailability, that is, the percutaneous absorption rate (see above). The ADI values are generally based on bioassays in which animals are exposed orally. Therefore, a route-to-route adjustment will be applied for dermal exposures. Thus, the HI for dermal exposure will be calculated by (Babich, 1989, p. 21):

$$HI_{D,j} = \frac{ADD_{D,j}}{ADI \cdot B}$$

where:  $HI_{D,j}$ , hazard index for dermal exposure by the D.j scenario, unitless;  $ADD_{D,j}$ , average daily dose from the dermal scenario D.j, mg/kg-d; ADI, acceptable daily intake, mg/kg-d; and B, bioavailability in the oral bioassay from which the ADI is derived, that is the fraction of the oral dose that is absorbed, unitless.

In cases where the oral bioavailability in the bioassay is unknown, a default value of one will be assumed, which is the same as making no adjustment. In principle, this adjustment could also be made for inhalation exposure. However, estimates of inhalation bioavailability are generally not available.

Certain scenarios, for example, direct exposure to spilled liquids or cleaning agents, occur intermittently. That is, they are not daily occurrences. The present risk assessment is concerned with chronic health effects, which are generally based on chronic or subchronic animal studies.

Therefore, for certain non-cancer effects, it may be appropriate to average these intermittent exposures over longer time periods. The average daily dose (ADD) may be adjusted as follows:

$$ADD_{TW,i} = \frac{ADD_i \cdot N_A}{T_A} \quad (A.43)$$

where:  $ADD_{TW,i}$ , time-weighted average daily dose from the  $i$ -th scenario, mg/kg-d;  $ADD_i$ , average daily dose from the  $i$ -th scenario, mg/kg-d;  $N_A$ , the of days that the exposure takes place during the averaging period, d; and  $T_A$ , averaging period, d.

The time-weighted ADD may be used with equation (2.12) or (2.13) to calculate the hazard index.

When an airborne pollutant acts directly on the respiratory tract, it may be convenient to express the exposure as the average airborne concentration ( $\text{mg}/\text{m}^3$ ), rather than the average daily intake (mg/kg-d) (compare CPSC, 1992, section VI.F.3.b.iii, p. 46654). In such cases, an "inhalation ADI" ( $ADI_I$ ). The inhalation ADI is actually a concentration, and is analogous to a reference concentration (RfC), may be derived from the NOAEL or LOAEL. By analogy to equation (A.40):

$$ADI_I = \frac{NOAEL}{UF_H \cdot UF_S}$$

Or

$$ADI_I = \frac{LOAEL}{UF_H \cdot UF_S \cdot UF_L} \quad (A.44)$$

where:  $ADI_I$ , inhalation ADI,  $\text{mg}/\text{m}^3$ ; the NOAEL and LOAEL are in  $\text{mg}/\text{m}^3$ ; and the uncertainty factors, UF's, are as defined above.

When the inhalation ADI is used, the hazard index becomes:

$$HI_{I,j} = \frac{ADE_{I,j}}{ADI_I} \quad (A.45)$$

where:  $HI_{I,j}$ , hazard index for exposure scenario I,j, unitless;  $ADE_{I,j}$ , time-weighted average daily exposure from scenario I,j,  $\text{mg}/\text{m}^3$ ; and  $ADI_I$ , "inhalation ADI,"  $\text{mg}/\text{m}^3$ .

Exposures to the same chemical from different scenarios may be combined by summing the HI values from different scenarios, where appropriate:

$$HI_{Total} = \sum_i HI_i \quad (A.46)$$

where:  $HI_{Total}$ , hazard index summed over different scenarios; and  $HI_i$ , hazard index from scenario  $i$ .

Note that equation (2.15) should only be applied to exposures for the same FR chemical. Care must also be taken to combine exposures only when it is reasonably foreseeable for the same individual to be exposed by all of the scenarios to be combined.

## B. Cancer

The lifetime average daily dose (LADD) is used to estimate cancer risk. The LADD is calculated from the ADD as follows:

$$LADD_i = \frac{ADD_i \cdot N_Y \cdot Y}{365.25 \cdot Y_E} \quad (\text{A.47})$$

where: LADD<sub>i</sub>, lifetime average daily dose from the *i*-th scenario; ADD<sub>i</sub>, average daily exposure from the *i*-th scenario, mg/kg-d; N<sub>Y</sub>, number of days per year that the product is used or that the exposure scenario occurs, d/y; Y, number of years of exposure, y; 365.25, number of days per year, d/y; Y<sub>E</sub>, average life expectancy, y.

Note that the number of years of exposure Y is not necessarily the same as the average lifetime of upholstered furniture Y<sub>F</sub>, which appears in equation (2.7). A consumer is likely to be exposed to many different pieces of furniture in a lifetime. The different pieces may be treated with different FR chemicals or none at all.

The lifetime individual excess cancer risk is calculated by:

$$R_i = Q \cdot LADD_i \quad (\text{A.48})$$

where: R<sub>i</sub>, lifetime individual excess cancer risk from the *i*-th scenario; Q, unit cancer risk, or cancer potency, (mg/kg-d)<sup>-1</sup>; and LADD<sub>i</sub>, lifetime average daily dose from the *i*-th scenario, mg/kg-d.

Dermal exposure estimates include an adjustment for bioavailability, that is, the percutaneous absorption rate (see above). The ADI values are generally based on bioassays in which animals are exposed orally. Therefore, a route-to-route adjustment will be applied for dermal exposures (Babich, 1989, p. 21). Thus, the cancer risk from dermal exposures will be calculated by:

$$R_{D,j} = \frac{Q \cdot LADD_{D,j}}{B} \quad (\text{A.49})$$

where: R<sub>D,j</sub>, lifetime individual excess cancer risk from the D<sub>j</sub> scenario; Q, unit cancer risk, or cancer potency, (mg/kg-d)<sup>-1</sup>; LADD<sub>D,j</sub>, lifetime average daily dose from the D<sub>j</sub> scenario, mg/kg-d; and B, bioavailability in the oral bioassay from which the unit risk is derived, that is the fraction of the oral dose that is absorbed, unitless.

When the cancer risk is to be based on the airborne concentration, the lifetime average daily exposure (LADE) is given by:

$$LADE_{I,j} = \frac{ADE_{I,j} \cdot N_Y \cdot Y}{365.25 \cdot Y_E} \quad (A.50)$$

where:  $LADE_{I,j}$ , lifetime average daily exposure from scenario I,j,  $mg/m^3$ ;  $ADE_{I,j}$ , average daily exposure from scenario I,j,  $mg/m^3$ ;  $N_Y$ , number of days per year that the product is used, d/y;  $Y$ , number of years of exposure, y; 365.25, number of days per year, d/y;  $Y_E$ , average life expectancy, y.

Then, the lifetime individual excess cancer risk is:

$$R_{I,j} = Q_I \cdot LADE_{I,j} \quad (A.51)$$

where:  $R_{I,j}$ , lifetime individual excess cancer risk from scenario I,j;  $Q_I$ , unit cancer risk, or cancer potency, by the inhalation route,  $(mg/m^3)^{-1}$ ; and  $LADE_{I,j}$ , lifetime average daily exposure by scenario I,j,  $mg/m^3$ .

The risks from exposures to the same chemical from different scenarios may be combined by summing the risks from each scenario, where appropriate:

$$R_{Total} = \sum_i R_i \quad (A.52)$$

where:  $R_{Total}$ , individual excess cancer risk summed over different scenarios; and  $R_i$ , individual excess cancer from scenario  $i$ .

Note that equation (2.21) should only be applied to exposures for the same FR chemical. Care must also be taken to combine exposures only when it is reasonably foreseeable for the same individual to be exposed by all of the scenarios to be combined.

The population risk, that is, number of excess cancers per year in the population, is given by (Babich, 1989, p. 24):

$$R_p = \frac{R \cdot N_E}{Y_E} \quad (A.53)$$

where:  $R_p$ , number of cancers per year;  $R$ , individual excess cancer risk, unitless;  $N_E$ , exposed population; and  $Y_E$ , average life expectancy, years.



United States  
**CONSUMER PRODUCT SAFETY COMMISSION**  
Washington, D.C. 20207

**MEMORANDUM**

**DATE:** October 1, 2001

**TO :** Dale Ray, Project Manager for Upholstered Furniture, Directorate for Economic Analysis

**Through :** Mary Ann Danello, Ph.D., Associate Executive Director for Health Sciences *mad*  
Lori E. Saltzman, M.S., Director, Division of Health Sciences *LS*

**FROM :** Michael A. Babich, Ph.D., Chemist, Division of Health Sciences *MAB*

**SUBJECT :** Exposure to Flame Retardant Chemicals in Residential Upholstered Furniture with Fire Blocking Barriers

The U.S. Consumer Product Safety Commission (CPSC) has been investigating the hazards associated with the small open flame ignition of upholstered furniture fires. The CPSC staff developed a draft performance standard to address these hazards (CPSC 1997). While furniture manufacturers would be free to choose the means of complying with a CPSC standard, manufacturers reported that, in most cases, they would treat the upholstery cover fabrics with flame retardant (FR) chemicals. However, in some cases, FR treatments may not be practical. Therefore, the CPSC staff developed an alternative test to be used when a fire-blocking barrier is placed between the cover fabric and foam.

Some barriers are constructed of inherently ignition-resistant materials, while others may be made of conventional fabric treated with one of the same FR treatments proposed for use in cover fabrics. The CPSC staff conducted an exposure and risk assessment of the use of FR chemicals in upholstered furniture cover fabrics (Babich and Thomas 2001). This memorandum discusses the potential exposure and risk from FR chemicals in fire blocking barriers.

Fire blocking barriers are placed beneath the cover fabric. Therefore, for similar FR chemical treatments, the exposure to FR chemicals in barriers is likely to be less than, or at worst

no greater than, the exposure from FR-treated cover fabrics. This assumes that similar amounts of FR chemicals and similar application methods are used in the barrier and cover fabrics.

For example, the CPSC staff previously concluded that upholstered furniture cover fabrics treated with phosphonic acid, (3-[[hydroxymethyl]amino]-3-oxopropyl)-, dimethyl ester (PA) would not present a hazard to consumers (Babich and Thomas 2001). Based on the available data, PA is not considered "toxic" as defined by the Federal Hazardous Substances Act (FHSA). Therefore, the conclusion that PA is not hazardous to consumers would apply equally to fire-blocking barriers.

The CPSC staff also concluded that additional information on the identity and toxicity of reaction by-products is needed to determine whether fabrics treated with tetrakis(hydroxymethyl) phosphonium chloride (THPC) may be hazardous (Babich and Thomas 2001). Exposure from barriers treated with THPC, and any resulting risk, is likely to be less than the exposure from THPC-treated cover fabrics. In either case, however, the possible risk is unknown. Therefore, additional information is needed, whether THPC is to be used in cover fabrics or barriers.

## **References**

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

Consumer Product Safety Commission (CPSC) (1997) Briefing Package on Upholstered Furniture Flammability: Regulatory Options for Small Open Flame and Smoking Material Ignited Fires. U.S. Consumer Product Safety Commission, Bethesda, MD 20814. October 1997.

**TAB H**



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

JUL 12 1999

OFFICE OF  
PREVENTION, PESTICIDES AND  
TOXIC SUBSTANCES

Mr. Ron Medford  
Assistant Executive Director, Hazard Identification and Reduction  
U.S. Consumer Product Safety Commission  
4330 East West Highway  
Bethesda, MD 20814-4408

Dear Ron:

To help coordinate our respective agencies' activities on the use of flame retardant chemicals in residential furniture, I thought it would be useful to provide you with some information on what EPA considers in developing a Significant New Use Rule (SNUR) and in responding to the Significant New Use Notifications (SNUN) which are submitted to EPA in response to the SNUR. This information may be of use to you in your work on your upholstered furniture rulemaking, and some of your information might prove equally useful to us in finalizing the SNUR and in assessing the SNUNs. By sharing information and working together, we will be able to avoid a wasteful duplication of effort.

The Toxic Substances Control Act (TSCA) Section 5(a)(2) requires that, in designating a "significant new use" of a chemical substance, we consider relevant factors specifically including:

1. the projected volume of manufacturing and processing of a chemical substance;
2. the extent to which a use increases the type or form of exposure of human beings or the environment to a chemical substance;
3. the extent to which a use increases the magnitude and duration of exposure of human beings or the environment to a chemical substance; and
4. the reasonably anticipated manner and methods of manufacturing, processing, distribution in commerce, and disposal of a chemical substance.

A SNUR is a notice and comment rulemaking procedure. In developing the SNUR we may consider relevant routes of exposure associated with the use of a chemical for the significant new use, including applicable occupational, industrial, residential, environmental, and/or general public exposure scenarios. We also may consider existing uses of such chemicals. As part of the rulemaking, these supporting analyses are subject to public review and comment.

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Our proposed SNUR will cover flame retardant chemicals which are not currently used in residential furniture upholstery. The SNUR will specify that anyone wishing to manufacture, import, or process a chemical for use as a flame retardant in residential furniture upholstery would have to notify the EPA at least 90 days before manufacturing, importing, or processing the chemical for that use. We believe that this SNUR would help to ensure that companies would not introduce certain potentially hazardous chemicals into the residential environment while attempting to meet CPSC's new flammability standard for residential furniture without our first having an opportunity to review the new use and take further regulatory action, if needed, to control those activities.

Persons subject to SNURs must comply with the same notice requirements and EPA regulatory procedures as submitters of premanufacture notices (PMNs) on new chemicals under section 5(a)(1) of TSCA. These requirements include certain information submission requirements. Following receipt of the SNUN, the information is reviewed and an assessment of the hazards, exposures, and risks is conducted by EPA. This review draws on data submitted with the SNUN, other information available to the Agency, and exposure and release modeling. The review of each SNUN can be characterized as including a review of the life cycle of the chemical, including: (1) manufacture of the substance domestically for the significant new use; (2) processing of the substance for the significant new use (e.g., reaction of intermediates, or blending with other substances); (3) the specific new use of the substance or products containing the substance; and (4) disposal or destruction of the substance as a result of the significant new use. Predicted releases of the substance to ambient and indoor air, surface water, soil and ground water are used to estimate environmental concentrations and determine potential human and environmental exposures. Exposures are estimated for workers, consumers, and members of the general population. EPA may take regulatory action under TSCA section 5(e), 5(f), 6, or 7 to control the activities for which it has received a SNUN.

I am confident that the joint working group our two staffs have set up to share information on flame retardant chemical issues will continue to make progress in a timely manner. Given the timing of our two proceedings, I believe that you might be able to use the information and analyses we are preparing for the SNUR, or subsequently in response to SNUNs, to assist in your development of environmental and economic impact analyses for your flame retardant standards rulemaking.

This cooperative effort by our two agencies is an excellent example of federal coordination that will benefit American citizens. Between us, we will both improve the fire safety of residential furniture and help to prevent the introduction of potentially hazardous chemicals into the home. By sharing information and utilizing each others' expertise, we can

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avoid duplicating work and cut the costs of our regulatory efforts. I hope that our joint work in this area can serve as a template for future projects addressing other consumer product issues where our statutory and regulatory programs complement each other as well as they do here.

Feel free to contact me at any time.

Sincerely,



Joseph S. Carra  
Deputy Director  
Office of Pollution Prevention and Toxics



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**

WASHINGTON, D.C. 20460

FEB 26 2001

OFFICE OF  
PREVENTION, PESTICIDES, AND  
TOXIC SUBSTANCES

**Mr. Ronald L. Medford**  
Assistant Executive Director  
for Hazard Identification and Analysis  
U.S. Consumer Product Safety Commission  
4330 East West Highway  
Bethesda, MD 20814

Dear Mr. Medford:

The Consumer Product Safety Commission (CPSC) has requested assistance from the Environmental Protection Agency (EPA) to support a new residential upholstered furniture flammability standard. EPA is pleased to assist CPSC in its efforts to protect consumers. Our plan to support your action is discussed below. We believe our cooperative efforts will help improve the fire safety of furniture while protecting against potential health and environmental impacts.

Based on conversations with your office, it appears that in order to meet the CPSC standard, residential upholstered furniture cover or barrier fabrics might have to be treated with a flame retardant (FR) chemical substance. CPSC has identified sixteen (16) chemicals that are most likely to be used to meet the CPSC standard. In order to guard against potential health and environmental impacts, EPA will evaluate these chemicals for inclusion in a Toxic Substances Control Act (TSCA) section 5(a)(2) Significant New Use Rule (SNUR). A SNUR requires persons who intend to manufacture, import, or process a substance for a use identified by EPA as a significant new use (in this case, use as a flame retardant on residential upholstered furniture fabric) to notify EPA at least 90 days before commencing such activities.

Under TSCA section 5(a)(2), in determining whether a particular use of a chemical substance is a significant new use, EPA must consider all relevant factors, including:

- 1) the projected volume of the manufacturing and processing of the chemical substance;
- 2) the extent to which the use changes the type or form of exposure of human beings or the environment to the chemical substance;
- 3) the extent to which the use increases the magnitude and duration of exposure of human beings or the environment to the chemical substance;
- 4) the reasonably anticipated manner and methods of manufacturing, processing, distribution in commerce, and disposal of the chemical substance.

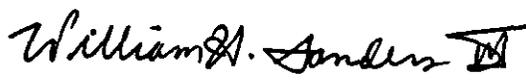
EPA may consider human and environmental exposure as well as toxicity when evaluating whether a particular potential use of a substance is a significant new use.

During the 90 day significant new use notice review period, EPA toxicologists, chemists, biochemists, engineers, and experts in other disciplines work together to assess the potential risks to humans or the environment from the significant new use. If necessary, EPA can prohibit or limit the use before it begins. In assessing the risks from the significant new use, EPA draws on data submitted with the notice, other information available to the Agency, and exposure and release modeling. The review of each notice can be characterized as including a review of the life cycle of the chemical, including: (1) manufacture of the substance domestically for the significant new use; (2) processing of the substance for the significant new use (e.g., reaction of intermediates, or blending with other substances); (3) the specific new use of the substance or products containing the substance; and (4) disposal or destruction of the substance as a result of the significant new use. Predicted releases of the substance to ambient and indoor air, surface water, soil, and ground water are used to estimate environmental concentrations and determine potential human and environmental exposures. Exposures are estimated for workers, consumers, and members of the general population.

With respect to the CPSC residential upholstered furniture standard, EPA will evaluate the FR chemicals identified by CPSC for inclusion in a possible SNUR. We are considering a SNUR that would prohibit the use of listed chemicals as a flame retardant on residential upholstered furniture pending review by EPA. Our ability to issue such a SNUR would be affected if it is determined that any of the chemicals are now being used for that purpose.

We realize that development of this proposed SNUR needs to be coordinated to the greatest extent possible with your efforts to develop a new residential upholstered furniture flammability standard. We believe this approach will achieve the objectives of both CPSC and EPA in protecting the health and safety of the public and the environment.

Sincerely,

  
William H. Sanders III, Dr. P.H., P.E.  
Director, Office of Pollution Prevention  
and Toxics



United States  
**CONSUMER PRODUCT SAFETY COMMISSION**  
Washington, D.C. 20207

**MEMORANDUM**

**DATE:** March 14, 2001

**TO :** Dale Ray, Directorate for Economic Analysis, Project Manager for Upholstered Furniture

**Through :** Mary Ann Danello, Ph.D., Associate Executive Director for Health Sciences *maD*  
Lori E. Saltzman, M.S., Director, Division of Health Sciences *LS*

**FROM :** Michael A. Babich, Ph.D., Chemist, Division of Health Sciences *maB*

**SUBJECT :** Priority Ranking of Flame Retardant Chemicals for a Possible Significant New Use Rule (SNUR)

**Background**

The U.S. Consumer Product Safety Commission (CPSC) is considering a draft performance standard to address the hazard of small open flame ignitions of upholstered furniture. Small open flame sources include cigarette lighters, matches, and candles. Such ignitions of upholstered furniture are associated with an estimated 80 deaths, 350 injuries, and \$32 million in property damage per year in the U.S. Although furniture manufacturers would be free to choose the means of complying with the draft standard, they would probably apply flame retardant (FR) chemicals to furniture fabrics to meet the draft standard (Parkes, 1998). In addressing the hazard associated with the small open flame ignition of upholstered furniture, the CPSC staff is working to develop a performance standard to reduce furniture ignitions without creating other hazards, such as toxicity, to consumers. Thus, the staff is assessing the potential risks to consumers from exposure to FR chemicals in upholstered furniture.

As part of the risk assessment process for FR chemicals, the Commission held a public hearing in May 1998. In its testimony, the Fire Retardant Chemicals Association (FRCA) provided a list of 16 chemicals or chemical classes (Table 1) that its members would market for use in upholstered furniture if the draft standard were adopted (Parkes, 1998). The CPSC Directorate for Health Sciences (HS) staff has completed toxicity reviews on these 16 chemicals/chemical classes. The CPSC Directorate for Laboratory Sciences, Division of Chemistry (LSC) staff conducted migration (leaching) studies with five different FR-treated

fabrics. Under an interagency agreement with CPSC, staff of the National Health and Environmental Effects Research Laboratory (NHEERL), U.S. Environmental Protection Agency (EPA) conducted *in vitro* percutaneous absorption studies with three radiolabeled FR chemicals (Hughes, 2000). The CPSC staff has performed risk assessments on 8 FR chemicals, which are a subset of the list proposed by FRCA (Babich and Thomas, 2001).

As part of CPSC's FY99 appropriations, Congress provided funds for an independent study by the National Research Council (NRC), National Academy of Sciences of the "toxic risk" associated with the use of flame retardant chemicals in upholstered furniture. The NRC concluded that eight of the 16 chemicals/chemical classes studied "can be used on residential furniture with minimal risk" (NRC, 2000, p. 11). The NRC also recommended that exposure studies be conducted before the remaining eight chemicals/classes are used.

The CPSC staff has requested that EPA develop a draft significant new use rule (SNUR) for the use of FR chemicals in upholstered furniture. The SNUR would address potential risks to consumers, workers, and the environment. If adopted, the EPA SNUR could be used to obtain additional toxicity or exposure data where needed. At the request of CPSC, the National Institute for Occupational Safety and Health (NIOSH) is reviewing the potential occupational exposures and health effects associated with the use of FR chemicals in textile and upholstered furniture manufacturing.

The purpose of this memorandum is to prioritize the 16 FR chemicals or chemical classes for possible inclusion in a draft SNUR. Criteria for ranking will include: results of risk assessments performed by NRC and CPSC, toxicity, the potential for exposure, and the availability of toxicity and exposure data.

## **Discussion**

Toxicity reviews. The CPSC staff reviewed all the available toxicity data on the 16 FR chemicals/classes, including: all published studies identified through the National Library of Medicine databases, Toxic Substances Control Act test submissions (TSCATS), unpublished data submitted to CPSC, testimony at the May 1998 public hearing, and standard references (Bittner, 2000; Bittner, 1999a-d; Bittner and Ferrante, 1999; Ferrante, 1999a-f; Hatlelid, 1999a-h; see also Babich and Saltzman, 1999). The data evaluated included acute and chronic toxicity, eye and skin irritation, and sensitization. The toxicity reviews include over 30 individual compounds. The extent of the database is summarized in Table 1. For some FR's—such as antimony trioxide; decabromodiphenyl oxide; and some aromatic phosphates—the database is fairly extensive. In other cases—such as phosphonic acid, (3-{{hydroxymethyl} amino}-3-oxopropyl)-, dimethyl ester; tris(chloropropyl) phosphate; and some inorganic compounds—very few toxicity studies are available. Overall, many of the chemicals have not been tested for carcinogenicity, reproductive function, and neurotoxicity. Most of the studies were by the oral route of administration, whereas the primary route of exposure from textiles is dermal.

The staff evaluated the available data for each chemical and classified them as either “known,” “probably,” or “possibly” toxic in humans, as defined in the CPSC chronic hazard guidelines (CPSC, 1992). Any chemical that is either “known” or “probably” toxic in humans is considered “toxic” under the FHSA. 16 CFR 1500.3 (c) (2)(ii). A number of chemicals did not satisfy the FHSA definition of “toxic.” This does not necessarily mean that they are “safe” or “non-toxic.” The FHSA does not define “non-toxic” or “safe.” It only defines what is toxic or hazardous. Acceptable daily intake (ADI) values were calculated when sufficient information was available. The results of the toxicity reviews are summarized in Table 2.

NRC report. The NRC Subcommittee on Flame Retardant Chemicals performed risk assessments for 16 FR chemicals (NRC, 2000). The most toxic chemical in each of the classes proposed by FRCA was selected to represent each class. For the most part, no exposure data were available (Table 3). The NRC concluded that eight of the 16 chemicals/chemical classes studied “can be used on residential furniture with minimal risk,” including: hexabromocyclododecane; decabromodiphenyl oxide; alumina trihydrate; magnesium hydroxide; zinc borate; ammonium polyphosphates; phosphonic acid, (3-{{[hydroxymethyl] amino}-3-oxopropyl)-, dimethyl ester; and tetrakis (hydroxymethyl)phosphonium chloride (NRC, 2000, p. 11). The NRC also recommended that exposure studies be conducted before the remaining eight chemicals/classes are used, including: antimony trioxide; antimony pentoxide and antimonates; calcium and zinc molybdates; dimethyl phosphonate (organic phosphonates); tris(chloropropyl) phosphate; tris(1,3-dichloropropyl-2)phosphate; tricresyl phosphate (aromatic phosphate plasticizers); and chlorinated paraffins.

CPSC staff risk assessment. The CPSC staff performed quantitative risk assessments on 8 FR chemicals (Babich and Thomas, 2001). The 8 chemicals represent an attempt to further prioritize the list of 16 chemicals/classes proposed by FRCA (Parkes, 1998). These chemicals are considered to be the most likely to be used in upholstered furniture, because they are currently used to treat either: fabrics in upholstered furniture sold in the U.K., foams in furniture sold in California, or apparel fabrics. In conducting the risk assessments, the staff performed migration studies with various solvents, including saline, citric acid, aqueous upholstery cleaner, and chlorinated solvent (Bhooshan and Cobb, 2000). These studies were used to estimate dermal exposure, as well as oral exposure in children. FR-treated upholstery fabrics available for migration studies were treated with antimony trioxide (AT); decabromodiphenyl oxide (DBDPO); hexabromocyclododecane (HBCD); phosphonic acid, (3-{{[hydroxymethyl] amino}-3-oxopropyl)-, dimethyl ester (PA); and tetrakis(hydroxymethyl)phosphonium chloride (THPC). Data with surrogate compounds or data submitted by the manufacturer were used to estimate migration of cyclic phosphonate ester (CPE); 2-ethylhexyl diphenyl phosphate (EHDP); and tris(1,3-dichloropropyl-2)phosphate (TDCP). Mathematical models were used to estimate inhalation exposure to particles and vapors.

*In vitro* percutaneous absorption data for DBDPO, HBCD, and TDCP were obtained through a cooperative agreement with NHEERL (Hughes, 2000). *In vivo* data for CPE were submitted by the manufacturer. Data obtained with tricresyl phosphate were used as a surrogate for EHDP. Percutaneous absorption data were not available for AT, PA, TDCP, and THPC.

Given the number of data gaps in the CPSC staff risk assessment, the conclusions are subject to revisions as additional data are obtained. Nonetheless, the CPSC staff concludes that CPE, DBDPO, EHDP, HBCD, and PA are not likely to present a hazard to consumers (Table 4). For CPE, DBDPO, and HBCD the hazard index was 0.01 or less, even with very conservative exposure assumptions. Furthermore, HBCD is considered possibly toxic in humans, based on limited evidence of toxicity in animals. There was inadequate evidence for the toxicity of PA in animals. Therefore, HBCD and PA do not satisfy the FHSA definition of "toxic" and, by definition, are not hazardous. However, the availability of toxicological data on PA is very limited.

Inhalation of AT particles is a possible hazard. The CPSC staff estimated a hazard index of 0.26 for non-cancer lung effects (inflammation, fibrosis) and a lifetime cancer risk of 1.2 per million. However, given the uncertainty in the exposure assessment for inhalation, which is entirely based on mathematical models, the possibility of a more substantial hazard cannot be ruled out without data on inhalation exposure.

Based on the risk assessment, the staff concludes that TDCP is likely to present a hazard, as the hazard index and cancer risk were estimated to be well above acceptable levels. However, exposure estimates were based on a surrogate compound and mathematical models. Empirical data on migration and emissions from treated fabrics are needed to confirm these conclusions.

Additional data are needed to assess the potential risk from THPC-treated fabrics. THPC is a reactive chemical that polymerizes within the fabric fibers. Roughly 10 percent of the total phosphorus present in treated fabric was extracted by saline or other solvents. However, THPC was not detected in the extracts. The identity of the phosphorus compounds present in the extracts is unknown. Additional information on the identity and toxicity of the migrating compounds is needed.

## **Recommendations**

The CPSC staff proposes a high, medium, or low priority for each of the 16 FR chemicals/classes proposed for use in upholstered furniture (Table 5). These suggested priorities will be used by the EPA staff, along with other information, in deciding which FR chemicals should be included in the draft SNUR. The priorities are based on the potential hazard to consumers. Potential risks to workers or the environment were not considered. The rankings and justification are discussed below.

**High priority.** High priority compounds include: antimony trioxide; antimony pentoxide and antimonates; tris(chloropropyl)phosphate; tris(1,3-dichloropropyl-2)phosphate; tetrakis(hydroxymethyl)phosphonium chloride; aromatic phosphates; the alkyl phosphonates (dimethyl phosphonate and dimethyl methylphosphonate); chlorinated paraffins, and the molybdates. Antimony trioxide presents a possible hazard due to inhalation of particles, based on modeled exposures. Exposure data are needed to determine whether this possible hazard is significant. The related antimony . . . to be similar in toxicity to

antimony trioxide, although few toxicity data are available. Dermal absorption of antimony compounds is expected to be low, but no data are available.

Tris(chloropropyl)phosphate and tris(1,3-dichloropropyl-2)phosphate are structurally related to tris(2,3-dibromopropyl)phosphate, which is no longer produced in the U.S. due to concerns about carcinogenicity. Although few toxicity data are available for the monochlorophosphate, the dichlorophosphate was carcinogenic and toxic in animal studies, and exposure data are lacking for both compounds. The CPSC risk assessment estimated substantial cancer and non-cancer hazards for the dichlorophosphate using surrogate compounds and mathematical models to estimate exposure. It should be noted that there has been some confusion regarding the correct nomenclature for tris(chloropropyl)phosphate (reviewed in Babich and Saltzmann, 1999). As a result of this confusion, toxicity data for the commercial product, which is a mixture of isomers, have been reported under various names and CAS numbers.

Tetrakis(hydroxymethyl)phosphonium salts (THPX) are reactive FR's that polymerize within fabric fibers. These compounds are of concern due to their toxicity, but they are not present in the finished product. Unidentified by-products are present in aqueous extracts of treated fabrics. Information on the identity and toxicity of the by-products are needed to assess the potential risks to consumers.

The aromatic phosphates are a broad group of compounds that are currently used in upholstery foams and are likely to be used to back-coat fabrics if the draft standard is adopted. In most cases, the toxicity database is adequate, although no exposure data are available. Most of these compounds exhibit neurotoxicity and other effects. ADI values range from 0.01 to 1.0 mg/kg-d. The CPSC staff estimated that EHDP (ADI = 1.0 mg/kg-d) probably would not be hazardous to consumers, but exposure data are needed to confirm this conclusion (Babich and Thomas, 2001). The NRC estimated that tricresyl phosphate (mixture of isomers) (ADI = 0.01 mg/kg-d) may be hazardous using conservative exposure assumptions, and concluded that exposure data are needed.

The alkyl phosphonates (dimethyl phosphonate and dimethyl methyl phosphonate) are of concern due to toxicity and the lack of exposure data. Little is known about the toxicity of the molybdates; the NRC subcommittee estimated a hazard index of 10 for dermal exposure. The chlorinated paraffins are of concern due to toxicity and the lack of exposure data.

Medium priority. Both CPSC and the NRC subcommittee concluded that phosphonic acid, (3-{[hydroxymethyl] amino}-3-oxopropyl)-, dimethyl ester (PA) is not likely to present a hazard to consumers. However, limited toxicity data are available for PA. The only subchronic study, 21 days duration, did not include histopathological examination of all major organs. No studies on reproductive, developmental, neurotoxicity, or carcinogenicity have been reported. The NRC based its conclusion, in part, on the assumption that exposure would be negligible, because PA forms cross-links with fabric fibers. However, studies conducted by CPSC show that some migration of organophosphorus compounds into aqueous media occurs. As is the case with THPC, the identity of the chemical species migrating from PA-treated fabric is unknown.

Low priority. The low priority FR's are those compounds which the CPSC staff or the NRC subcommittee concluded would not present a hazard to consumers. However the NRC and the CPSC risk assessments did not consider potential risks to workers or the environment. Low priority FR's include: decabromodiphenyl oxide; hexabromocyclododecane; cyclic phosphonate esters; zinc borate; alumina trihydrate; magnesium hydroxide; and the ammonium polyphosphates. Alumina trihydrate and magnesium hydroxide are over-the-counter antacids.

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**Table 1. Availability of Toxicity Data on Flame Retardant Chemicals<sup>a</sup>**

Chemical/Class <sup>b</sup>	CAS no. <sup>c</sup>	Acute	Subchronic	Chronic	Repro/Dev	Neurotox <sup>d</sup>	Genotox	Human <sup>e</sup>
1 Antimony trioxide (AT)	1309-64-4	X	X	X	X	-	X	X
2 Decabromodiphenyl oxide (DBDPO)	1163-19-5	X	X	X	X	-	X	-
3 Hexabromocyclododecane (HBDCD)	3194-55-6	X	X	X	X	-	X	-
	13674-84-5							
4 Tris(chloropropyl) phosphate (TCPP) (mixture of 4 isomers)	76649-15-5 76025-08-6 6145-73-9	X	-	-	-	-	X	-
5 Tris(1,3-chloropropyl-2) phosphate	13674-87-8	X	X	X	X	X	X	-
6 3-oxopropyl-, (3-[[hydroxymethyl] amino]- (Pyrovatex®)	20120-33-6	X	?	-	-	-	X	-
7 Tetrakis (hydroxymethyl) phosphonium salts (THPX) (Proban®):								
Chloride salt (THPC)	124-64-1	X	X	X	X	?	X	-
Sulfate salt (THPS)	55566-30-8	X	X	X	?	?	X	-
Compound with urea (THPC-urea)		X	-	-	X	?	X	-
Polymer (THPOH/NH <sub>3</sub> )	27104-30-9	?	-	-	-	-	X	-
8 Organic phosphonates:								
Dimethyl phosphonate (DMHP)	868-85-9	X	X	X	X	X	X	-
Dimethyl methylphosphonate (DMMP)	756-79-6	X	X	X	X	X	X	-
Cyclic phosphonate esters (CPE) (mixture of monomer and dimer) (Antiblaze N/NT®) <sup>f</sup>	41203-81-0 42595-45-9	X	X	-	X	-	x	-
9 Aromatic phosphates:								
t-Butylphenyl diphenyl phosphate (BDDP)	56803-37-3	-	X	-	-	X	X	X
2-Ethylhexyl diphenyl phosphate (EHDP)	1241-94-7	X	X	X	X	X	X	-
Isodecyl diphenyl phosphate (IDDP)	29761-21-5	X	X	-	-	X	X	-
Phenol isopropylated phosphate (PIP)	86937-41-7	X	X	-	-	X	-	X
Santicizer 141 (>90% EHDP)		X	X	-	X	X	X	-
Santicizer 148 (>90% IDDP)		X	X	-	X	X	X	-

	Santizer 154 (TPP + BDP)	X	X	-	X	X	X	-
	o-Tricresyl phosphate (o-TCP)	X	X	-	X	X	X	X
	Tricresyl phosphate (TCP) (isomers)	X	X	-	X	X	X	X
	Triphenyl phosphate (TPP)	X	X	-	X	X	X	X
<b>10</b>	Chlorinated paraffins	X	X	X	X	X	-	X
	63449-39-8 + 20 others							
<b>11</b>	Molybdates:							
	Calcium molybdate	X	X	-	-	-	-	-
	Zinc molybdate	X	-	-	-	-	-	-
<b>12</b>	Antimonates:							
	Antimony Pentoxide	X	-	-	-	-	-	X
	Sodium antimonate	X	-	-	-	-	-	-
<b>13</b>	Zinc borate (mixture of zinc oxide and boric anhydride)	-	-	-	-	-	-	-
	Zinc oxide	X	X	-	X	X	X	X
	Boric anhydride	X	X	-	-	-	-	X
	Boric acid	X	X	X	X	X	-	X
<b>14</b>	Alumina trihydrate	X	X	-	X	X	X	X
<b>15</b>	Magnesium hydroxide	-	-	-	-	-	-	X
<b>16</b>	Ammonium polyphosphates (Antiblaze LR2 and Antiblaze LR4)	X	-	-	-	-	-	X

- a X indicates availability of data; ? limited data available; -, no data available.
- b These 16 flame retardant (FR) chemicals or chemical classes were proposed by the Fire Retardant Chemicals Association for use in upholstered furniture.
- c CAS no., Chemical Abstract Service number.
- d For neurotoxicity, a ? means that although a neurotoxicity per se was not performed, neurotoxic effects were observed in other tests.
- e Human data includes clinical reports and epidemiological studies.
- f Monomer: phosphonic acid, methyl-, (5-ethyl-2-methyl-1,3,2-dioxaphosphorinan-5-yl)methyl methyl ester, P-oxide.
- g Dimer: phosphonic acid, methyl-, bis[(5-ethyl-2-methyl-1,3,2-dioxaphosphorinan-5-yl)methyl] ester, P, P'-oxide.

**Table 2. Toxicity Summary of Flame Retardant Chemicals**

Chemical/Class <sup>a</sup>	Acute Toxicity <sup>b</sup>	Chronic Toxicity <sup>c</sup>	Endpoint <sup>d</sup>	NOAEL/LOAEL <sup>e</sup> (mg/kg-d)	UF	ADI <sup>f</sup> (mg/kg-d)
1 Antimony trioxide (AT)	Oral	B	O	230	100	2.3
		Inhalation	B	C,O	(9 µg/m <sup>3</sup> ) L	1,000
2 Decabromodiphenyl oxide (DBDPO)		B	O	3,200 L	1,000	3.2
3 Hexabromocyclododecane (HBDCD)		B	R,D,N,O			ND <sup>f</sup>
4 Tris(chloropropyl) phosphate (TCPP) (mixture of 4 isomers)	T	I				ND
5 Tris(1,3-chloropropyl-2) phosphate	T	B	C			ND
6 Phosphonic acid, (3-[[hydroxymethyl] amino]-3-oxopropyl)-, dimethyl ester (PA) (Pyrovatex®)		I				ND
7 Tetrakis (hydroxymethyl) phosphonium salts (THPX) (Proban®):						
Chloride salt (THPC)	T	B	N,O	2.7 L	1,000	0.0027
Sulfate salt (THPS)	T	B	O	3.6	100	0.036
Compound with urea (THPC-urea)	T	B	D	50	100	0.5
Polymer (THPOH/NH <sub>3</sub> )		I				ND
8 Organic phosphonates:						
Dimethyl phosphonate (DMHP)	T	B	O	36	100	0.36
Dimethyl methylphosphonate (DMMP)		B	R,O	180 L	1,000	0.18
Cyclic phosphonate esters (CPE) (mixture of monomer and dimer) (Antiblaze N/NT®) <sup>g</sup>		B	O	1,000	100	10
9 Aromatic phosphates:						
t-Butylphenyl diphenyl phosphate (BPDP)		I				ND
2-Ethylhexyl diphenyl phosphate (EHDP)		B	O	100	100	1.0
Isodecyl diphenyl phosphate (IDDP)		C	O			ND
Phenol isopropylated phosphate (PIP)		C	N,O			ND
Santicizer 141 (.90% EHDP)	T	B	O	100	100	1.0
Santicizer 148 (>90% IDDP)		B	O			0.01
Santicizer 154 (TPP + BPDP)		C	N,O			ND
o-Tricresyl phosphate (o-TCP)		A	N			ND
Tricresyl phosphate (TCP) (isomers)		B	R,N,O	50 L	1,000	0.05
Triphenyl phosphate (TPP)		C	N,O			ND

		B	C,D,O <sup>h</sup>	10	100	0.1
10	Chlorinated paraffins					
11	Molybdates:					
	Calcium molybdate	C	O			ND
	Zinc molybdate	C	O			ND
12	Antimonates:					
	Antimony Pentoxide	I				ND
	Sodium antimonate	I				ND
13	Zinc borate (mixture of zinc oxide and boric anhydride)	T	C	R,D,N,O		ND
14	Alumina trihydrate	A	N,O			45 (AI) <sup>i</sup>
15	Magnesium hydroxide	A	O			68 <sup>j</sup>
16	Ammonium polyphosphates (Antiblaze LR2 and Antiblaze LR4)	I				ND

- <sup>a</sup> These 16 flame retardant (FR) chemicals or chemical classes were proposed by the Fire Retardant Chemicals Association for use in upholstered furniture.
- <sup>b</sup> Acute toxicity as defined in FHSA regulations: T, toxic; H, highly toxic.
- <sup>c</sup> Chronic toxicity as defined under the FHSA 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.
- <sup>d</sup> Chronic toxicity endpoint(s): C, cancer; D, developmental; N, neurotoxicity; R, reproductive; O, other (e.g., liver toxicity).
- <sup>e</sup> Doses are in mg/kg-d by the oral route, except where indicated. L indicates LOAEL.
- <sup>f</sup> ND, not determined.
- <sup>g</sup> Monomer: phosphonic acid, methyl-, (5-ethyl-2-methyl-1,3,2-dioxaphosphorinan-5-yl)methyl methyl ester, P-oxide.
- <sup>h</sup> Dimer: phosphonic acid, methyl-, bis[(5-ethyl-2-methyl-1,3,2-dioxaphosphorinan-5-yl)methyl] ester, P,P'-oxide.
- <sup>i</sup> Toxicity depends on the chain length and level of chlorine substitution. Carcinogenicity was observed with a short-chain product.
- <sup>j</sup> Maximum therapeutic dose, as aluminum.
- <sup>k</sup> Maximum therapeutic dose.

**Table 3. NRC Report on FR Chemicals**

<b>Chemical/Class<sup>a</sup></b>	<b>CAS no.<sup>b</sup></b>
<b>Compounds presenting a minimal hazard:</b>	
Hexabromocyclododecane (HBDCD)	3194-55-6
Decabromodiphenyl oxide (DBDPO)	1163-19-5
Alumina trihydrate	21645-51-2
Magnesium hydroxide	1309-42-8
Zinc borate	1332-07-6
Ammonium polyphosphates	68333-79-9
Phosphonic acid, (3-[[hydroxymethyl] amino]-3-oxopropyl)-, dimethyl ester (PA) (Pyrovatex®)	20120-33-6
Tetrakis (hydroxymethyl) phosphonium chloride (THPC)/Tetrakis (hydroxymethyl) phosphonium salts:	124-64-1
<b>Compounds requiring exposure data:</b>	
Antimony trioxide (AT)	1309-64-4
Antimony pentoxide and sodium antimonate:	1314-60-9
	15432-85-6
Calcium and zinc molybdate	7789-82-4
	61583-60-6
Dimethyl phosphonate (DMHP)/Organic phosphonates	868-85-9
Tris(chloropropyl) phosphate (TCPP) (mixture of 4 isomers)	13674-84-5
	76649-15-5
	76025-08-6
	6145-73-9
Tris(1,3-chloropropyl-2) phosphate	13674-87-8
Tricresyl phosphate (TCP) mixture of isomers/Aromatic phosphate plasticizers	1330-78-5
Chlorinated paraffins	63449-39-8 + 20 others

**Table 4. CPSC risk assessment of selected FR chemicals.**

FR chemical	"Toxic" under the FHSA <sup>a</sup>	Migration data available <sup>b</sup>	Percutaneous absorption data available <sup>c</sup>	"Hazardous" under the FHSA <sup>b</sup>
Antimony trioxide (AT)	Yes	Yes	No	Possibly <sup>d</sup>
Cyclic phosphonate ester (CPE)	Yes	No	Yes	No
Decabromodiphenyl oxide (DBDPO)	Yes	Yes	Yes	No
2-Ethylhexyl diphenyl phosphate (EDHP)	Yes	No	No	Probably not <sup>f</sup>
Hexabromocyclododecane (HBCD)	No	Yes	Yes	No
Phosphonic acid, (3-[[hydroxymethyl]amino]-3-oxopropyl)-, dimethyl ester (PA)	No	Yes	No	No
Tetrakis (hydroxymethyl) phosphonium chloride (THPC)	Yes	Yes	No	Insufficient data <sup>g</sup>
Tris (1,3-dichloropropyl-2) phosphate (TDCP)	Yes	No	Yes	Possibly <sup>g</sup>

<sup>a</sup> Satisfies the Federal Hazardous Substances Act definition of "toxic."

<sup>b</sup> Whether migration (leaching) data were available to assess liquid-mediated dermal exposure.

<sup>c</sup> Whether percutaneous absorption data were available.

<sup>d</sup> Exposure to airborne particle-bound AT is estimated to be at or near the acceptable levels for non-cancer effects and cancer. Additional data on inhalation exposure are needed to determine whether AT may present a hazard by inhalation.

<sup>e</sup> This chemical may possibly present a hazard if the treated fabric is exposed to non-aqueous cleaners. A surrogate compound was used to estimate dermal exposure. Migration data are needed to confirm these conclusions.

<sup>f</sup> THPC is a reactive chemical. The principal chemical species migrating from the treated fabric could not be identified. Additional information on the identity and toxicity of the migrating species are needed.

<sup>g</sup> A surrogate compound was used to estimate dermal exposure. Data on liquid-mediated migration and the emission of vapor phase TDCP are needed to confirm this conclusion.

**Table 5. Priority ranking of FR chemicals for a possible SNUR**

Chemical/Class	CAS no.	Priority	Comment
1 Antimony trioxide (AT)	1309-64-4	High	Inhalation toxicity concern; lack of inhalation exposure data.
2 Decabromodiphenyl oxide (DBDPO)	1163-19-5	Low	Minimal risk in CPSC and NRC risk assessments.
3 Hexabromocyclododecane (HBDCCD)	3194-55-6	Low	Minimal risk in CPSC and NRC risk assessments.
4 Tris(chloropropyl) phosphate (TCPP) (mixture of 4 isomers)	13674-84-5		
	76649-15-5	High	Lack of toxicity and exposure data; structural analogues are carcinogenic.
	76025-08-6		
6145-73-9			
5 Tris(1,3-chloropropyl-2) phosphate Phosphonic acid, (3-[[hydroxymethyl] amino]-	13674-87-8	High	Carcinogenic; lack of exposure data.
6 3-oxopropyl)-, dimethyl ester (PA) (Pyrovatex®)	20120-33-6	Medium	Limited toxicity data.
7 Tetrakis (hydroxymethyl) phosphonium salts (THPX) (Proban®):		High	Lack of information on identity and toxicity of by-products migrating from treated fabrics.
	Chloride salt (THPC)	124-64-1	
	Sulfate salt (THPS)	55566-30-8	
	Compound with urea (THPC-urea)		
	Polymer (THPOH/NH <sub>2</sub> )	27104-30-9	
8 Organic phosphonates:			
Dimethyl phosphonate (DMHP)	868-85-9	High	Toxicity concern; no exposure data.
Dimethyl methylphosphonate (DMMP)	756-79-6	High	Toxicity concern; no exposure data.
Cyclic phosphonate esters (CPE) (mixture of monomer and dimer) (Antiblaze N/NT®)	41203-81-0		
	42595-45-9	Low	Minimal risk in CPSC risk assessment.

<b>9</b>	<b>Aromatic phosphates:</b>		High	Neurotoxicity concern; lack of exposure data.
	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)	86937-41-7		
	Santitizer 141 (>90% EHDP)			
	Santitizer 148 (>90 % IDDP)			
	Santitizer 154 (TPP + BPDP)			
	o-Tricresyl phosphate (o-TCP)			
	Tricresyl phosphate (TCP) (isomers)	1330-78-5		
	Triphenyl phosphate (TPP)	1145-86-6		
<b>10</b>	<b>Chlorinated paraffins</b>	63449-39-8 + 20 others	High	Toxicity, carcinogenicity concern; lack of exposure data.
<b>11</b>	<b>Molybdates:</b>		High	Toxicity concern; lack of exposure data.
	Calcium molybdate	7789-82-4		
	Zinc molybdate	61583-60-6		
<b>12</b>	<b>Antimonates:</b>		High	Lack of toxicity and exposure data.
	Antimony Pentoxide	1314-60-9		
	Sodium antimonate	15432-85-6		
<b>13</b>	<b>Zinc borate (mixture of zinc oxide and boric anhydride)</b>	1332-07-6	Low	Minimal risk in NRC risk assessment.
	Zinc oxide	1314-13-2		
	Boric anhydride	1303-86-2		
	Boric acid	10043-35-3		
<b>14</b>	<b>Alumina trihydrate</b>	21645-51-2	Low	Minimal risk in NRC risk assessment. Used therapeutically as antacid.
<b>15</b>	<b>Magnesium hydroxide</b>	1309-42-8	Low	Minimal risk in NRC risk assessment. Used therapeutically as antacid.
<b>16</b>	<b>Ammonium polyphosphates (Antiblaze LR2 and Antiblaze LR4)</b>	68333-79-9	Low	Minimal risk in NRC risk assessment.



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February 15, 2001  
HETA 99-0279

Dale R. Ray  
Project Manager  
Directorate for Economic Analysis  
U.S. Consumer Product Safety Commission  
4330 East West Highway  
Bethesda, Maryland 20814

Dear Mr. Ray:

On June 28, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the U.S. Consumer Product Safety Commission (CPSC). The CPSC is considering a flammability standard for all residential upholstered furniture products, and this standard could result in all upholstery fabric being treated with flame retardants (FRs). The potential for increases in worker exposure to FRs during the treatment of upholstery fabric prompted the CPSC to request NIOSH assistance in determining current levels of worker exposure. This letter is an update of the NIOSH investigators' activities on this project, and provides our observations and conclusions from these activities. It will also provide information on plans and upcoming activities related to this project.

## **BACKGROUND**

The CPSC provided NIOSH with a list of thirteen U.S. companies that either used FRs to treat fabric or worked with FR-treated fabric. The NIOSH investigators contacted each of these companies and collected background information on their operations. This information was used to determine which companies were considered candidates for inclusion in this study. Of the thirteen companies, five were considered not to be candidates due to lack of FR use, and two others refused participation in this study. Hence, six companies were included in the FR study.

Site visits were conducted at each of the six companies. Of the six facilities visited, five were directly involved in the application of FRs. The sixth facility did not treat fabric with FRs, but used FR-treated upholstered fabric to manufacture office furniture. During the site visits, the NIOSH investigators observed the FR treatment processes and operations, collected information and data related to the FRs, and discussed safety and health issues related to FR use with management and worker representatives.

Originally, CPSC provided a list of 16 chemical compounds that could potentially be used as FRs in treating upholstered fabrics. In subsequent conversations with CPSC representatives, NIOSH investigators learned that four of the 16 will most commonly be used in most FR treatments.<sup>1</sup> Three of the four "commonly used" FR chemical compounds (DBDPO, antimony trioxide, THPC) were used in the fabric finishing plants that were visited by the NIOSH investigators.

Flame retardants are applied to fabric using one of two techniques: direct-coating (also called knife-over or back-coating) and immersion treatment (roller-coating or kiss-coating). Four of the five facilities involved in the application of FRs used the direct-coating process, and one used the immersion process. Management representatives at some of the companies informed us that there are variations to these two processes, but the basic principles and techniques are similar from one process to the next.

## **PROCESS DESCRIPTIONS**

In the direct-coating operation, a FR latex back-coating is applied to the reverse (non-decorative) side of the fabric. The latex used in this operation is a viscous liquid, and FRs are added to the latex by the chemical supplier. A system of rollers horizontally moves the fabric under a trough that runs the width of the fabric. The liquid latex is "whipped" with air, which creates a foam-like substance. The latex foam is poured into the trough, and is gravity-applied to the backside of the fabric through a slit in the bottom of the trough. Immediately downstream of the slit is a knife or edge, which scrapes the excess latex from the fabric, and leaves a thin layer of latex on the back of the fabric. The latex-coated fabric next goes through an oven, and the latex hardens and bonds to the fabric.

The FRs used in the latex are DBDPO and antimony trioxide. Formaldehyde is also present in small amounts (less than 0.5%) in the FR formulation, and ammonia is sometimes used as a viscosity modifier. In most cases, the back-coating of fabric (with FRs) using the direct-coating method accounts for less than 10% of each company's business, and the number of workers at each facility involved in this process is 10 or fewer.

Immersion treatment consists of dipping the fabric into a bath which contains the FR, and squeezing the fabric using rollers to remove the excess liquid (referred to as padding). The fabric is dried and exposed to ammonia in an enclosed chamber. The ammonia reacts with the FR to form an inert polymer which is trapped within the fabric's fibers. Next, the fabric is dipped in hydrogen peroxide to facilitate chemical oxidation of any remaining phosphorous and to remove odors and other insoluble compounds. Finally, the fabric is washed and dried, and a mechanical treatment is performed to control for width and shrinkage.

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<sup>1</sup> These compounds are decabromodiphenyl oxide (DBDPO), antimony trioxide, tetrakis hydroxymethyl phosphonium chloride (THPC), and phosphonic acid, 3-((hydroxymethyl)amino)-3-oxopropyl-dimethyl ester (PA). It should be noted that DBDPO is often used in combination with antimony trioxide, and that THPC is commonly sold and used as an 80% aqueous solution.

The FR compound used in this process is THPC, which contains a small amount of formaldehyde (less than 1%) as a contaminant. There is a variation of this process which is called roller coating, which involves a turning roller partly submerged in the FR-containing solution. The FR is applied when the fabric contacts the roller; contact time is a major factor in this application process.

## **PRELIMINARY EXPOSURE ASSESSMENT**

### ***Inhalation Exposure***

Vapor pressure is a property of a chemical compound that is related to the chemical's ability to vaporize at a given temperature. The lower the vapor pressure, the less likely the chemical will vaporize and pose an inhalation hazard. The FR compounds used in direct-coating and immersion treatment have the following vapor pressures at normal room temperatures (68-75°F): DBDPO:  $3.5 \times 10^{-8}$  millimeters of mercury (mm Hg), antimony trioxide:  $1 \times 10^{-10}$  mm Hg, and THPC: 1 mm Hg for the 80% aqueous solution. In comparison, water has a vapor pressure of 18 mm Hg, and isopropyl (rubbing) alcohol as a vapor pressure of 33 mm Hg.

Considering these very low vapor pressures for the FR compounds, it is improbable that they will produce significant vapors at normal room temperatures. It is important to note that the rate of vaporization can be increased by heating the process, and ovens are used in both the direct-coating and immersion treatment operations to dry the fabric. However, in all cases the ovens were enclosed, and the vapors emitted during this operation were vented outside of the building.

Inhalation exposures may occur either when a chemical is in a vapor form in the workplace or if an aerosol of the chemical is produced by a process or operation. Certain mechanical processes will aerosolize a liquid, and the droplets may be small enough to be inhaled. Generally, liquid aerosols are produced through spraying or misting operations. Neither of these operations occurred during the FR coating or treatment processes observed during the NIOSH site visits.

Respirable dust particles can be generated by mechanical action related to material handling and movement, or by processing activities associated with an operation. The direct-coating and immersion processes observed during the NIOSH site visits were not dusty operations. Material handling and movement activities did not produce a visible dust.

### ***Dermal Exposure***

There is little likelihood for workers to receive dermal exposures to the FRs, as workers do not contact the FRs or wet/uncured fabric.

## **TOXICITY ASSESSMENT**

The NIOSH assessment of the toxic potential of DBDPO, antimony trioxide, and THPC was based on the recently released report: Toxicological Risks of Selected Flame Retardant

Chemicals<sup>2</sup> This report was prepared by the National Research Council, Commission on Life Sciences, Board on Environmental Studies and Toxicology, Committee on Toxicology, Subcommittee on Flame Retardant Chemicals. Although a valuable guide, the NRC report is limited (as acknowledged by the authors of the report) in several important areas.

First, no FRs can be said to be entirely lacking in health effects (regardless of route of exposure) because of the limited research data that exist. Oral and inhalation routes of exposure are largely unstudied in humans as well as in laboratory animals. In many cases, information concerning anticipated health effects from the dermal route of exposure is minimal, at best.

Second, the NRC report was designed to answer the question of consumer safety as it relates to chronic FR exposure. The exposure modeling that formed the basis of the safety determinations for this report cannot be applied to the types of exposures likely to be encountered by workers in the fabric finishing industry. The NRC model for dermal exposure is based on a person sitting on a piece of furniture (upholstered with an FR-treated fabric) for extended periods of time. To estimate a "worst case" scenario, the Subcommittee on Flame Retardants assumed a situation of maximal exposure to the skin and minimal barrier to transmission of the FR chemical. Workers employed in those companies visited by the NIOSH investigators are likely to be subjected to lower dermal levels of exposure to FRs than those postulated in the NRC models because handling finished bolts of cloth does not approximate the "worst case" scenario considered by the Subcommittee.

Third, the NRC report reviewed the toxicity information of pure chemicals and not that of FRs that are incorporated into a finished fabric product. Workers in the fabric finishing industry are not directly involved in the formulation of the FR chemicals and therefore, have little contact with the pure ingredients that formed the basis of the studies reviewed by the NRC. Moreover, workers in the plants evaluated by NIOSH used FRs that either exist in an ionic form or as a polymer that is applied to fabric. These physical properties limit the ability of the chemicals to penetrate the dermal barrier.

## SUMMARY OF TOXIC POTENTIAL OF FLAME RETARDANTS

### *DBDPO*<sup>3</sup>

DBDPO, a brominated aromatic FR is the most widely used FR of its chemical class. The Subcommittee on Flame Retardants could find no evidence that this chemical posed either a non-cancer or a cancer hazard regardless of exposure route. The inhalation and ingestion routes of

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<sup>2</sup> Subcommittee on Flame-Retardant Chemicals, Committee on Toxicology, Board on Environmental Studies and Toxicology, Commission on Life Sciences, National Research Council [2000]. *Toxicological Risks of Selected Flame-Retardant Chemicals*. Washington, DC: National Academy Press.

<sup>3</sup> Decabromodiphenyl oxide. In: *Toxicological Risks of Selected Flame-Retardant Chemicals*, pp. 72-98.

exposure are likely to be relatively unimportant to workers in the fabric finishing industry. The dermal route of exposure is also presumed to be minimal as DBDPO is applied as a backing to fabric via an automated system involving little if any skin contact on the part of the workers. The FR is "baked on" to the fabric in an enclosed oven and is then mechanically rolled. Toxicologic risk, therefore, appears to be minimal.

#### *Antimony Trioxide*<sup>4</sup>

Antimony trioxide, which has FR properties of its own, is often combined with DBDPO and other brominated FRs to enhance their inherent flame retardant properties. Antimony trioxide has been studied as a putative carcinogen via the inhalation route. It is known to cause pneumoconiosis, chronic cough, and upper airway inflammation following chronic exposure. These findings are most common in workers exposed to antimony trioxide through the processing of ore or use of the antimony trioxide as a raw ingredient. Workers in the facilities visited by the NIOSH investigators are likely to be exposed to antimony trioxide in the form of a polymer, bound to DBDPO, and applied as described above. Exposure risk via the inhalation route, both cancerous and noncancerous, is mitigated by the agent being bound in a viscous polymer.

The Subcommittee on Flame Retardants was unable to comment on the cancerous properties of antimony trioxide by either the dermal or oral route of exposure, but neither route is likely to represent a significant exposure risk to workers in the facilities visited by the NIOSH investigators. In its native state, antimony trioxide is an ionic compound that is unlikely to be absorbed to any significant degree through the skin. The automated application of antimony trioxide in a polymer form further limits exposure and, hence, further limits toxicologic risk. Opportunities for oral exposure to antimony trioxide in the facilities visited by the NIOSH investigators do not appear to be significant.

#### *THPC*<sup>5</sup>

THPC is produced by the reaction of formaldehyde, phosphine, and hydrochloric acid. Relatively little is known about the potential health risks posed by exposure to this chemical as was highlighted by the NRC report. Although reports of contact dermatitis among children wearing night clothes treated with THPC-based FRs exist, these appear to be uncommon. In one study, 100 volunteers ranging in age from 9 to 63 years of age showed no skin reactions or evidence of skin sensitization upon re-challenge with a patch of THPC-treated fabric.

The Subcommittee on Flame Retardants was unable to draw any conclusions as to the carcinogenicity of THPC via the dermal or inhalation routes of exposure; risk of cancer via the

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<sup>4</sup> Antimony Trioxide. In: *Toxicological Risks of Selected Flame-Retardant Chemicals*, pp. 229-261.

<sup>5</sup> Tetrakis(hydroxymethyl) Phosphonium Salts. In: *Toxicological Risks of Selected Flame-Retardant Chemicals*, pp. 417-439.

oral route of exposure was deemed "not likely." Non-cancer toxic risks by dermal, inhalation, or oral routes of exposure were believed to be minimal or zero. Like antimony trioxide, THPC is an ionic chemical not absorbed through the skin. Moreover, THPC polymerizes after application to fabric, further limiting chances for significant exposure.

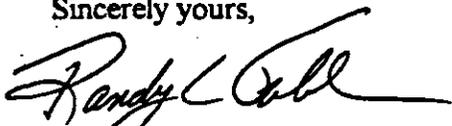
Prior to completion of the polymerization process, the potential exists for inhalation exposure to workers employed in the application of this FR. The application of THPC in the plant visited by the NIOSH investigators was, however, largely enclosed, thereby limiting risk of exposure. Risks may be increased, however, during repair or maintenance of the equipment when workers may be required to enter otherwise closed off spaces. The potential toxic effects of such an exposure are, at this time, unknown.

### SUMMARY AND FUTURE ACTIVITIES

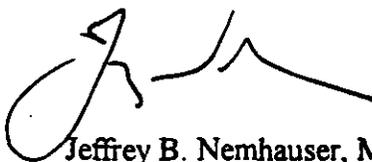
Although NIOSH investigators visited only 5 fabric finishing companies involved in the application of flame retardant chemicals, it is our opinion that our findings may be generalized to the fabric finishing industry, as a whole. The low vapor pressures of the commonly used FR compounds limits their potential for exposure. An understanding of the operations used to coat or treat fabric also suggests that there is very little potential for workers to be exposed to these compounds. Aerosols are not generated as part of these operations, and there appears to be little opportunity for dermal exposures to occur. In addition, a review of the toxicologic information associated with DBDPO, antimony trioxide, and THPC indicates that these substances probably do not pose a significant health hazard to workers in the fabric finishing industry.

Nonetheless, the NIOSH investigators are not aware of any worker exposure data for FRs in upholstered fabric coating/treatment operations. Though the NIOSH investigators believe these exposures are low, it is important from a public health standpoint to document these exposures. Hence, the NIOSH investigators will be conducting exposure assessment site visits at companies that employ the direct-coating and immersion treatment operations. These site visits will probably occur during March, April, or May of 2001. In addition to measuring exposures to the FR compounds, the protocol will also include exposure assessments for other chemicals associated with these processes (*i.e.* formaldehyde, ammonia, and hydrogen peroxide). If you have any questions related to this project, please contact either Dr. Reh at (513) 841-4107, or Dr. Nemhauser at (513) 458-7117.

Sincerely yours,



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# TAB I

**Economic Analysis of Regulatory Options to Address  
Small Open Flame Ignitions of Upholstered Furniture**

**Charles L. Smith  
Directorate for Economic Analysis  
U.S. Consumer Product Safety Commission**

**October 2001**

## EXECUTIVE SUMMARY

In an Advance Notice of Proposed Rulemaking (published in the June 15, 1994, *Federal Register*) the U.S. Consumer Product Safety Commission (CPSC) announced its determination that ignitions of upholstered furniture by small open flames might constitute an unreasonable risk to the public. In response, the staff of the CPSC developed a standard intended to address small open flame ignition hazards of residential upholstered furniture. The draft standard specifies tests to determine the ignition resistance of upholstery fabrics, barrier materials, and dust cover materials. The CPSC's Directorate for Economic Analysis has prepared an *Economic Analysis of Regulatory Options to Address Small Open Flame Ignitions of Upholstered Furniture*. This analysis describes the businesses and products that would be affected by the standard if it were adopted by the CPSC, the estimated societal benefits and costs that would result from compliance with the rule, and regulatory options.

In its present form, the standard would primarily affect the more than 1,500 manufacturers of residential upholstered furniture, and the 100 to 200 textile manufacturers that derive a significant share of their revenues from fabric for household furniture. Nearly all of the affected firms would be classified as small businesses. The likely means of compliance would be the treatment of upholstery fabrics with fire retardant (FR) chemicals, use of barrier materials, and use of inherently-flame retardant materials.

The benefits of the standard would be the reduction in deaths, injuries, and property damage from ignitions of furniture by small open flame sources (e.g. lighters, matches, and candles). The annual losses are estimated to average 55 deaths, 375 injuries, and \$32.7 million in property damage, with a total annual value of \$372 million during the 1995-1998 time period. The average expected lifetime hazard cost for furniture items in use that are likely to ignite from small open flames is about \$12.50 per item. Evaluation of CPSC laboratory test data from open flame testing of chairs covered with FR treated and untreated fabrics indicate that FR fabric treatments are estimated to result in a projected hazard reduction of 76% to 88%. Lifetime benefits of the standard are projected to be about \$9.50 to \$11.00 per affected item.

In addition to benefits associated with reductions of fires started from small open flames, testing data show that the draft standard would also result in a reduction in fires started by cigarettes and other smoking products. Estimated annual societal losses from these fires averaged 443 deaths, 805 injuries, and \$90.5 million in property losses, with an annual value of losses at about \$2,440 million over 1995-1998. Laboratory testing data suggest that furniture covered with cellulosic fabrics (e.g. cotton and rayon) is much more likely to be involved in fires than items covered with thermoplastic fabrics (e.g. polyester, polyolefin, and nylon), and the estimated societal losses per item of furniture are much greater for items with cellulosic fabrics. When the expected fire costs of cellulosic and thermoplastic fabrics are weighted by the current market shares

of fabrics being used, and adjusted to account for an expected future decline in smoking-related fire incidents, the average expected lifetime hazard costs for furniture items in use that are likely to ignite from cigarettes is \$62.74 per item. Evaluation of CPSC laboratory test data from cigarette ignition testing of chairs covered with FR treated and untreated fabrics finds that FR fabric treatments are estimated to result in a projected hazard reduction of 50% to 77%. Lifetime benefits are projected to be \$31.37 to \$48.31 per affected item, if the draft standard were adopted.

The combined estimated benefits from reductions in small open flame and cigarette-ignited fires expected over the useful product lives of complying furniture are projected to range from \$40.88 to \$59.32 per item. The projected aggregate gross benefits from furniture produced annually (30 million units) total about \$920 million to \$1,330 million.

Most of the costs of the standard would result from the use of upholstery fabrics that would be treated with FR chemicals to pass the standard's seating area test. The estimated average incremental increase in fabric costs to furniture manufacturers ranges from \$.62 to \$1.05 per linear yard. Costs of testing to confirm the ignition performance of the fabrics may range from \$.21 to \$.28 per linear yard. Estimated resulting increases in retail prices paid by consumers would range from about \$21.10 to \$33.80 per item of family room furniture requiring fabric treatment. Items requiring less fabric would incur lower costs and price increases. Furniture items made with FR barrier materials under untreated upholstery fabrics are estimated to incur retail price increases averaging \$41 to \$55 per item. Recordkeeping required by the rule is expected to result in average increases in retail prices of \$.63 per item.

The estimated aggregate costs of the standard to consumers range from \$515 to \$802 million annually. When compared to the estimated benefits of \$920 to \$1,330 million accruing over the life of the furniture items manufacturers each year, projected net benefits to society from the standard range from \$118 to \$815 million.

This report also evaluates possible alternatives to the standard, including revising the scope to include dining chairs and home office desk chairs, requiring product labeling that warns consumers about the flammability hazards, alternative effective dates, and the alternative of taking no regulatory action by the CPSC.

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## 1. INTRODUCTION

In 1993 the U.S. Consumer Product Safety Commission (CPSC) docketed a petition from the National Association of State Fire Marshals (NASFM) to initiate a proceeding to regulate hazards associated with upholstered furniture fires started by small open flame ignition sources, cigarettes, and larger open-flame sources. To address hazards associated with small open-flame ignitions, NASFM sought the adoption of California's Bureau of Home Furnishings Technical Bulletin 117 as mandatory requirements for upholstered furniture sold for consumer use in the U.S. Technical Bulletin 117 requires testing of the fabric and filling material components used to make furniture to assure their resistance to ignition from small open-flame sources. The Commission determined that ignitions of upholstered furniture by small open flames might constitute an unreasonable risk to the public and granted that part of the petition (while reserving judgment on the technical merits of the California standard). An Advance Notice of Proposed Rulemaking (ANPR) was published on June 15, 1994, in the *Federal Register*.

NASFM's petition also sought the adoption of the California Bureau of Home Furnishings Technical Bulletin 116, and some aspects of Technical Bulletin 117, to address hazards associated with ignitions of furniture by cigarettes and other smoking materials; action on this part of the petition was delayed pending CPSC staff review of the effectiveness of the voluntary activities of the furniture industry. Finally, the NASFM petition asked the Commission to adopt Technical Bulletin 133, which addresses large open-flame ignition performance of furniture; this was denied by the Commission on May 12, 1994.

This *Economic Analysis* discusses the impacts of various options for addressing the small open-flame hazard, including a standard developed by the staff that specifies testing protocols for furniture seating areas and dust covers. It provides information on the products and industries that are likely to be affected by actions taken to reduce upholstered furniture fires. The *Analysis* also discusses potential costs and benefits associated with requirements of the CPSC draft standard and selected alternatives. This report also discusses potential effects on small firms and other market impacts.

## 2. THE STANDARD: SCOPE AND TESTING PROVISIONS

The staff of the CPSC developed a standard that specifies tests to determine the ability of upholstered furniture to resist ignition when subjected to a small open-flame source (e.g., match, cigarette lighter, or candle). As drafted, the standard would apply to "moveable products that are primarily intended for seating use, and that contain a textile or other soft cover materials and cushions or other soft interior filling materials." The

standard applies to finished or ready-to-assemble articles of upholstered furniture (such as upholstered sofas, loveseats, sofa beds, rockers, recliners, and other chairs) that are:

- a. primarily intended for indoor use in residences;
- b. (either) (1.) constructed with an upholstered seating area, comprised of a contiguous upholstered seat and back, or seat and side (for the seating area test); or (2.) constructed with a dust cover under an upholstered seat (for the dust cover test);<sup>1</sup>
- c. manufactured or imported more than 18 months after the publication date of a final rule in the *Federal Register*.

Furniture items with upholstered seating areas can comply with the standard by using materials that pass either a seating area test or a barrier test. For the seating area test, mockups of the seating area would be subjected to a small butane flame for a period of 20 seconds. Seating area mockup upholstery fabrics are tested over a substrate of urethane foam (referred to as standard foam) cushioning. The flame source is applied at three different locations along the crevice. If the seating area upholstery fabrics withstand the 20-second exposure without continued combustion (as defined by the test procedures) they would be acceptable for use in the manufacture of furniture.

Alternatively, manufacturers may choose to comply with the standard by using a barrier material under the upholstery fabric. Acceptable barriers must pass the standard's barrier test, which subjects a mockup of an FR fabric-covered barrier over standard urethane foam to a small wooden crib fire (the Crib 5 Test of the UK regulations).

Furniture made with dust covers must comply with the dust cover test. This test subjects a horizontal sample of the dust cover material to a vertical flame for 20 seconds. The test is done at three locations on the dust cover sample. If continued combustion does not result, the material is approved for use.

The standard is described in more detail in the report by the Directorate for Engineering Sciences.<sup>2</sup>

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<sup>1</sup> A dust cover is fabric attached to the bottom of a chair, sofa, or other upholstered piece. Its purpose is to keep dust from accumulating in the item's interior, as well as to improve the appearance.

<sup>2</sup> Khanna, Rohit Z., "Draft Standard for Upholstered Furniture," Directorate for Engineering Sciences, CPSC, February 2001.

### 3. PRODUCTS AND INDUSTRIES POTENTIALLY AFFECTED

#### 3.1. Upholstered Furniture Manufacturing

The standard would address the flammability of fabrics used in the production of upholstered furniture. The largest class of furniture products that would be affected is upholstered furniture on wood frames and dual purpose sleep furniture such as sofa beds, commonly bought for use in living rooms and family rooms. Other types of affected products include upholstered metal, reed, and rattan furniture.

##### 3.1.1. Upholstered Furniture on Wood Frames and Dual-Purpose Sleep Furniture

Products referred to as "Household Upholstered Furniture" by the Census Bureau are classified in code 337121 of the North American Industrial Classification System (NAICS). More than 1,500 U.S. companies (with 1,706 establishments) manufacture upholstered household furniture or dual-purpose sleep furniture as their primary product. There are a large number of other firms that may also produce upholstered furniture as secondary products.

Although there is a large number of upholstered furniture manufacturers, the top four companies accounted for nearly 32 percent of the total value of wood upholstered furniture shipments in 1997 (the latest year for which industry concentration ratio data are available); the 50 largest companies accounted for about 69 percent.<sup>3</sup> Reports from the trade press indicate that the industry has become more concentrated in recent years, mainly through buyouts of firms by the larger companies. The firms that are brought into the larger corporate structure often retain their trade names and production facilities as new divisions. Recent mergers include La-Z-Boy's acquisition of Ladd in January 2000 and Bauhaus and Alexvale in 1999; La-Z-Boy is the number one upholstered furniture manufacturer (by dollar volume), and Ladd, Bauhaus, and Alexvale all previously ranked in the top 30.

The industry also includes many small establishments. The Bureau of the Census reports that, in 1997, 69 percent of all establishments manufacturing upholstered furniture as their primary product had fewer than 20 employees. By some measures, such as the U.S. Small Business Administration's (SBA's) definition for qualification for small business loans, a furniture manufacturing establishment is considered to be "small" if it has fewer than 500 employees. This would encompass all but 32 establishments (2 percent) in the industry.

The value of shipments of upholstered household furniture (NAICS 337121) by U.S. firms in 1997 (the latest *Census of Manufactures* year) was \$8.4 billion. Exports of

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<sup>3</sup> U.S. Census Bureau, U.S. Department of Commerce, *1997 Economic Census*, report EC97M31S-CR, "Concentration Ratios in Manufacturing," June 2001.

goods in two major product categories (upholstered seats, wood frame, and upholstered chairs, wood frame) had an estimated value of about \$200 million, or about 2 percent of the total value of shipments. Since the value of imports for these two product categories was about \$750 million, there were *net* imports of about \$550 million. The apparent consumption of upholstered furniture (domestic shipments plus imports, minus the value of exports) was about \$8.9 billion. Imports have grown in recent years. The value of imported upholstered seats and chairs on wood frames totaled about \$950 million in 1999<sup>4</sup> (which was about 10 percent of the value of shipments of upholstered household furniture in that year, \$9.4 billion<sup>5</sup>) and \$1.2 billion in 2000. Net imports in 2000 had a value of about \$1.0 billion. The leading country of origin (as in other recent years) was Italy, which accounted for 46 percent of the value of imports in 2000. Italy was followed by Canada (16 percent), Mexico (14 percent), and China (11 percent). These four countries accounted for 87 percent of the total value of imported upholstered seats and chairs on wood frames in 2000.<sup>6</sup>

### 3.1.2. Upholstered Metal Furniture

Upholstered metal household furniture would also be covered by the standard. This furniture is classified in NAICS 337124 (and previously in SIC 2514). The products in this industry group include metal household dining furniture, some of which are upholstered chairs. Upholstered dining chairs are not within the scope of the standard. NAICS 337124 also includes tubular metal, cast & wrought iron, and other metal chairs, rockers, and seating furniture. A total of 388 U.S. companies manufactured metal household furniture (upholstered and non-upholstered) as their primary product in 1997. These companies operated 420 establishments, only 11 of which had more than 500 employees. The number of establishments that are involved in the production of upholstered metal furniture, and the number of units of metal upholstered furniture shipped, are not provided by the Census data.

The last year that the value of shipments of upholstered metal household furniture was reported was in 1982. In that year, upholstered shipments were valued at \$9.9 million. This was less than 2 percent of "other metal household furniture" shipments of \$539.2 million. If the same proportion applies to "other metal household furniture" shipments of \$946 million in 1997, upholstered metal furniture shipments may have been about \$17 million. A significant percentage of upholstered metal furniture is probably outdoor furniture, which is not within the scope of the standard.

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<sup>4</sup> U.S. International Trade Commission data cited in *Furniture/Today*, June 12, 2000, p. 21.

<sup>5</sup> U.S. Census Bureau, *Annual Survey of Manufactures*, "Value of Shipments for Product Classes (NAICS 337124)," March 6, 2001.

<sup>6</sup> U.S. International Trade Commission data cited in *Furniture/Today*, April 30, 2001, p. 71.

### 3.1.3. Upholstered Reed and Rattan Furniture

Furniture made with reed and rattan frames (including willow, wicker, and cane) is included in NAICS 337125, *Household Furniture (except wood and metal)*. Domestic shipments of reed and rattan seating in 1992 totaled 262,000 units, with a value of shipments of \$53 million. Some part of this production was upholstered. The value of shipments of this type of furniture totaled \$69 million in 1997 (unit shipments were not reported). Eleven domestic companies reportedly had shipments totaling at least \$100,000 in 1997. Imports of reed and rattan seating furniture are significant, with a value of shipments totaling nearly \$100 million in 1999 and \$125 million in 2000, an unknown proportion of which was upholstered.<sup>7</sup> The leading countries of origin were China and the Philippines.

### 3.1.4. Other Upholstered Chairs

Upholstered furniture manufactured under contract for nonresidential settings is not likely to be covered by any regulatory alternative under consideration. However, items such as desk chairs marketed as residential products may be affected, if they have upholstered seats and backs, and the Commission decides to include them within the scope of the rule. The number of people maintaining home offices reportedly has grown significantly in recent years, rising from about 27 million in 1989 to 41 million in 1993, and 50 million in 1996.<sup>8</sup>

The Commission may also decide to include chairs intended for seating at dining or kitchen tables, and having upholstered seats *and* backs within the scope of the rule. These items are generally products of firms classified in the wood household furniture industry, NAICS 337122. The *Census of Manufactures* reports that nearly 5 million dining room chairs were shipped in 1997, with a value of shipments totaling about \$545 million. Census data are not reported separately for upholstered and non-upholstered dining chairs. In 1994, Heiden Associates surveyed participants in the voluntary industry program to improve the cigarette ignition resistance of furniture that was developed by the Upholstered Furniture Action Council (UFAC). Among the firms surveyed were manufacturers of upholstered dining room and kitchen seating. Heiden Associates estimated that the total value of shipments of such furniture that complied with the UFAC Program (and, therefore, had upholstered seats) was about \$250 million for 1993.<sup>9</sup> Based on the value of 1992 shipments (\$580 million), perhaps 3 to 4 million upholstered dining chairs were shipped by these UFAC participants. A large percentage of these items might not have had upholstered backs. Other firms that are not participants in the UFAC Program also manufacture upholstered dining furniture. Based

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<sup>7</sup> *IBID.*

<sup>8</sup> *Handbook of Furniture Manufacturing and Marketing*, AKTRIN Furniture Research, Oakville, Ontario, Canada, June 1994, p. 51.

<sup>9</sup> Heiden Associates, Inc., "Report on Survey of UFAC Members re: Compliance with Upholstered Furniture Cigarette Ignition Flammability Standard," December 15, 1994.