Tab H

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: December 12, 2005

TO : Margaret L. Neily, Mattress Flammability Project Manager

THROUGH: Hugh McLaurin, Associate Executive Director
Directorate for Engineering Sciences
Robert B. Ochsman, Ph.D.
Director, Division of Human Factors (ESHF)

FROM : Jonathan D. Midgett, Ph.D.
Engineering Psychologist, ESHF

SUBJECT : Human Factors Affecting Sampling on Mattress Surfaces

The Commission is considering a rule addressing deaths and injuries caused by mattress fires. One method to decrease the risks of mattress fires could result in flame retardant chemicals being incorporated in mattress construction. Mattress manufacturers could choose from many different flame retardant chemicals and a variety of construction methods for this purpose. Comments to the proposed rule have raised concerns that normal mattress use may expose consumers to some of these materials. This memorandum describes the human factors which may affect exposures to substances in mattress components and discusses the implications for sampling methods to assess these exposures.

Exposure to Mattress Surfaces

A large portion of consumers' lives (about a third of life) is spent in close association with mattresses. Besides being used for sleeping, mattresses commonly provide an area for multiple disparate daily activities. Mattresses have long lives, possibly getting passed around a family for decades before being discarded. Given this high level of use, an exposure analysis could consider many factors affecting mattress wear including normal sleep patterns, compression, soiling and many other potentially damaging events. Additionally, some human factors have the potential to mitigate exposures to mattress components, like the use of sleepwear, pillows, and sheets that form fabric barriers between consumers and mattress surfaces. Staff selected the factors addressed in this memo for consideration and acknowledges that a wider range of normal human events could be included in a more elaborate exposure analysis. The estimates presented in this memorandum represent above-average rates, but not worst-case. Worst-case estimates within subgroups of the mattress-using population might range up to five times higher; mechanical engineers commonly design equipment to withstand five times the product's expected forces.

The selection of factors used in an exposure analysis can be targeted to any subset within the exposed population. It is common to approach new analyses based on the most representative user groups, typically average consumers. Staff acknowledges that certain subsets of the

population, for instance seniors or people with disabilities, may have different mattress-use patterns than average consumers. Two typical groups, 50th percentile, middle-aged, male and female adult consumers and 50th percentile male and female 5-year old children were chosen to represent consumers for this preliminary exposure analysis. Children are considered separately because children have less body mass, tend to sleep longer than adults, can be expected to subject their mattresses to energetic jumping, and may still wet the bed sometimes. Five-year olds were chosen to represent children because this age group is more likely to have outgrown their crib mattresses which often have liquid-resistant ticking (e.g. vinyl or plastic) which could minimize exposures from within the mattress. Once a child outgrows a crib around 2 years of age, sometimes the crib's mattress is installed on a toddler bed which serves the growing child for a few more years. Children younger than 5 years old may also have various protective barriers on their beds or wear diapers when sleeping because of their higher likelihood of bedwetting.

Duration of Use

Adults sleep an average of about 8 hours a day; 5 year olds average 11 hours of sleep (Howard & Wong, 2001). Some consumers spend much longer than this in bed due to age, injury, or illness. People vary widely in the amount of sleep that they need.

A wide variation in the lifetime of a mattress should be expected. Although the International Sleep Products Association indicates that 10 years is the manufacturer recommended time to keep a mattress, consumers may keep them for longer. An expected average lifetime of a mattress of 14 years has been used by Tohamy (2004), based on Homan (1996). Consumers may discard mattresses after they become uncomfortably compressed, ripped, soiled, or otherwise seriously damaged. Consumers may keep mattresses with limited damage, if the overall comfort of the mattress is not affected (e.g., a rip on the edge or corner).

Mattress Wear

Mattresses experience a wide range of pressures, from gentle compression to forceful shearing. Dragging forces that stretch and scrape the fabric and compression forces probably comprise the majority of mattress wear and stress, originating in normal use, such as, but not limited to, consumers sliding into and out of beds, making, moving, flipping and playing on mattresses. Consumers may sit, lie, kneel, and jump on mattresses during various normal activities involving one person or multiple people at a time. These various pressures and stresses of daily mattress use contribute to the wear of a mattress' components over time.

An exposure analysis could estimate compression forces using measures of central tendency: 50th percentile adult males (45-54 years old) weigh 79.0 kg, 50th percentile adult females (45-54 years old) weigh 65.5 kg, 50th percentile 5-year old male children average 19.4 kg, and 50th percentile 5-year old females average 19.0 kg (EPA, 1997). Combined-gender averages of these weights (72.25 kg adult; 19.2 kg child) provide reasonable weights of typical users.

Body movement occurs intermittently during sleep, about 13% of sleep time for adults (Wellman, Bohannon & Vogel, 1999) with considerable individual variation expected. Over the lifetime of a mattress, these movements will contribute significant wear to the component materials in the mattress. The analysis of exposure to mattress components could consider this

accumulated stress and the potential degradation caused by aging and fatigue of components. Some mechanical pre-conditioning of mattress components, such as pounding or rolling, before sampling may somewhat mimic these accumulated stresses. Researchers could use the surface agitation rates found in industry standards for mattress wear performance testing before taking samples from mattress surfaces.

Besides movement and compression, mattresses experience warming from body heat, humidification from breathing, and dampening with body fluids like saliva, sweat, and urine. Quantifying the expected amounts of such exposures is challenging. Heat pre-conditioning of mattress samples in exposure studies can likely follow the performance tests from textile or mattress standards. Humidity from breath seems less significant than other factors. Saliva is likely to be secreted onto pillows, although it could potentially reach mattress surfaces, but since the unknown rates and amounts of nocturnal drooling are probably less voluminous than the other bodily fluids likely to soil mattresses, the contribution of saliva in wetting the mattress can be excluded from an exposure analysis; sweat and urine seem the more important factors. Physiologists can provide estimates of the amounts of sweat and urine produced by adults and children during a night's rest if surrogates are available. At ambient temperatures below 30° C, the human body loses approximately 900 ml per day (Brown & Stubbs, 1983). Health Sciences (HS) staff estimates that 300 ml is perspired during sleep.

Urine surrogates are relevant to represent exposures for children who do not achieve complete bladder control until middle or late childhood. Physicians estimate that at 5 years of age 15% to 25% of children still wet the bed; during adolescence (up to age 18 years) 1% to 3% of people may still face this problem (Theidke, 2003). Of course, very small children have less bladder control than 5-year olds, but they are commonly on crib mattresses which frequently have liquid-resistant ticking or use other barriers, which potentially affect the nature and the degree of exposure to substances within the mattress. For a 5 to 6 year old child, only two bed-wetting episodes per month are required for a diagnosis of "nocturnal enuresis." Of course, wetting can be more frequent than this, but *regular* bed-wetting can lead caregivers to consistently use alternative mattress covers and/or diapers to protect the bed. The issue for an exposure scenario is not how often children wet the bed, but rather the frequency that children wet the bed *without* their caregivers anticipating it. Staff could not locate such information, and so suggests a conservative estimate based on the diagnostic criteria mentioned above, i.e., twice per month.

The surface area affected by sweat equals the entire surface of the body, but urine exposures are not so straightforward. Urine wicks across the sheets and mattress surface, making it likely that portions of the surface areas of the thighs, buttocks, lower trunk and crotch could get wet. Without quantitative information about the average urine dispersion during nocturnal enuresis, staff must estimate this amount. Assuming some portion (for the sake of argument, assume 50%) of the anterior and posterior thighs (16% of total body area), the buttocks (5%), crotch (1%), and about a fifth of the lower trunk (20% of 13% = 3%) (Berkow, Fletcher & Beers, 1992) are in close proximity to wet mattress surfaces, then a tentative estimate for skin contact with the wet mattress might be about half of this total portion or *about 13%* of the total surface area of the body (16% (thighs) + 5% (buttocks) + 1% (crotch) + 3% (lower portion of trunk) = 25%/2 = 12.5%). This area is not necessarily a contiguous area occupying just one side of the body, but could be distributed all around the body in streaks and convoluted wet areas after several hours of tossing and turning. While this proportion lacks empirical validity, it has reasonable face validity with professional staff with child-rearing experience. When children wet

the bed, many could remain unaware of their bedwetting until morning because children sleep so soundly. Exposure could extend for significant periods of time because bedcovers can prevent the mattress from drying.

Potential Interface Barriers

Large portions of skin may be expected to contact a mattress, with cloth barriers like sheets and possibly also sleepwear between the skin and the mattress surface, although one or both may sometimes be absent. Significant regional and seasonal variations exist for the types and weights of sleepwear and bedclothes. Clothing will often consist of one layer of fabric, depending on the season. Some people may never wear clothes to bed, no matter what the season. In warm climates and seasons, lighter clothing may be more permeable to moisture and particulates, thereby increasing exposures beyond those experienced when wearing winter-weight sleepwear which might reduce contact with mattress surfaces. In colder climates and seasons, beds may have thicker covers which might serve to contain dusts released from mattresses in the bed more completely than more permeable summer-weight bedclothes, thereby creating more dense accumulations of dusts at the mattress-consumer interface. Some consumers may use a mattress pad made of several layers of fabric with interior batting beneath their fitted sheet, so some typical consumers may regularly have a three-layer mattress pad, one sheet, and one layer of sleepwear between their body and the mattress making a significant barrier between the mattress and the person on it. Pillows in a pillowcase add even more layers and some people use multiple pillows. However, since use of sheets and sleepwear is not universal, and the length of time spent in bed spans several hours every day, it seems acceptable to suggest that a conservative estimate of exposure to substances on mattress surfaces could assume that a significant portion of consumers will have only limited fabric barriers (if any) between them and the mattress surface.

Interface Pressures

Measuring the pressures experienced by the skin at the interface of the body with the mattress requires careful consideration. Fortunately, scientists have explored such mattress interface pressures for medical purposes. Physiologists studying the prevention of bed sores have found that the firmness of the mattress and box spring, as well as the firmness and shape of the mounting surface of the pressure sensor will affect the interface measurements (Bain, Scales & Nicholson, 1999). Using an anthropometrically representative mannequin called a "phantom" reclining on a soft mattress with electronic pressure sensors, Bain, et al, found small spots of maximum interface pressure reaching 2.3 to 3.0 PSI (1999). Firm mattresses produced higher forces than soft mattresses and the box spring's firmness created differences in pressure measurements of the same phantom/mattress combinations. Other research found that typical peak interface pressures on prone crash test mannequins were about 1 PSI (Shelton, Barnett & Meyer, 1998). This is a reasonable estimate, but staff acknowledges that higher forces can occur for brief periods during more playful activities than sleeping.

Skin Contact

During sleep, consumers of all ages will often toss and turn in bed which potentially allows nearly the complete surface area of the body to touch the mattress and sometimes wrap tightly in sheets and pajamas that have also touched mattress surface residues. Tossing and turning has the potential to distribute dusts from the mattress surface throughout the bedclothes and sleepwear. Because of this potential fabric permeability to dusts and the fact that consumers toss and turn in bed and may not wear anything, it seems reasonable for a conservative analysis to anticipate exposure over the entire surface area of the body. The combined-gender average of the total skin surface area of 50th percentile adults is 1.82 m^2 and 0.79 m^2 for 50th percentile 5-year children (EPA, 1997).

Ingestion

Quantifying ingestion amounts is extremely tentative. A mattress user's face and mouth may come into contact with the mattress surface for significant time periods depending on sleeping posture and pillow use. Small amounts of substances on the mattress surface may be ingested from this facial contact when users wipe their mouths or moisten their lips during and after sleep. Eating might occur in bed as well, not only with children, but adults, too. Mouthing of sheets or mattresses, although possible, does not seem likely to occur regularly enough to be considered a significant exposure route for adults.

However, if this route was included in an exposure estimate, the National Academy of Science's (NAS) Commission on Life Sciences (CLS) has used the rate of 1 hour daily of 50 cm^2 surface area of upholstery in their study of flame-retardant chemicals (NAS, 2000) for use in upholstered furniture. That estimate assumed exposures of a 1-year old child to furniture designed for day-time use. The CPSC's mattress exposure estimate requires consideration of furniture designed for night-time use when children are primarily asleep, and therefore interacting less vigorously with their environment. Furthermore, CPSC staff has chosen to examine older children (5 year olds) because younger children's mattresses are more likely to be waterproofed due to their higher likelihood of bedwetting. This waterproofing, with fluid-resistant ticking or mattress covers, is expected to reduce contact with flame retardant chemicals, and so would be inappropriate for an estimate of above-average exposures. Also, mouthing of non-body-part objects decreases across the lifespan, and notably after the age of 3 years. However, staff acknowledges that some mouthing of sheets and covers may occur in 5 to 15 year old children, but believes this event would be infrequent and slight. The NAS (2000) states that the actual oral exposures that they used are "hard to imagine" and could be "100-fold less" (page 51). Because mattresses have a different use pattern, and because the CPSC estimates focus on an older child, it seems reasonable to include the NRC's estimate in a modified form. Assuming that the 50 cm^2 was 100-fold more than actual exposures, then the actual exposures would be about 0.5 cm^2. If this actual estimate is increased 10 times to be conservative, this yields an oral exposure estimate of 5 cm^2 a day.

Additionally, the hand-to-mouth activity of small children seems to be a reasonable consideration for exposures to substances on mattresses. Small children may mouth their hands and fingers after touching their bed and bedclothes. Mouthing behavior decreases with age but is not completely extinguished in adulthood. Many behaviors could cause adults to ingest particulates from contaminated skin (i.e., moistening lips, eating in bed, kissing, or other intimate

contact). Quantifying the range of potential ingestion events is difficult, lacking convincing empirical evidence, and therefore unlikely to produce highly valid population estimates. However, in the interest of making a reasonable estimate, it is foreseeable for a typical consumer to lick their fingers during breakfast. A typical scenario for a 5-year old might reasonably consider ingestion of particulates from a portion of the pads of the index, thumb, and forefinger of both hands (each about 1 cm^2) added to 2 moistenings of the lips during the night with the tip of the tongue (each about 1 cm^2), which totals 8 cm^2. A typical scenario for an adult might consider ingestion from a portion of the pads of only the thumb and forefinger of a single hand (each about 2 cm^2) added to 2 moistenings of the lips during the night with the tip of the tongue (each about 1 cm^2), which totals 6 cm^2. As noted above, these are tentative estimates. Additionally, exposures during adult intimate activities[1] could possibly increase this estimate, but empirical data to support any estimate would be highly questionable, inevitably relying on self-reports from self-selected respondents with enormous variability.

Inhalation

Particulates in mattresses may become airborne during daily use. This may provide additional exposures to flame retardants by inhalation. An average sedentary adult male's air intake averages 0.6 m^3/hour; a sedentary child averages 0.4 m^3/hour (EPA, 1997). The inhalation rates "at rest" of 0.4 m^3/hour and 0.3 m^3/hour, respectively, could also be used, but not all of the hours spent on mattresses will be resting, so the sedentary average seems appropriate for a more conservative exposure analysis.

Other Factors

Other events with the potential to degrade mattresses could be considered in projects with more comprehensive descriptive goals than the current one. For instance, mattresses may be exposed to electric blankets, fan-forced heaters, direct sunlight, or rainfall from windows left open accidentally. Mattresses likely also experience occasional cleanings consisting of damp sponging after accidents from sickness (vomit, urine, etc.) or clumsiness (food, beverage). Household cleaners and water may occasionally be used on a mattress. Some consumers may use a vacuum cleaner on their mattress and some mattresses may never be cleaned. Empirically-derived rates for these events are unknown, but they could potentially contribute vigorous stresses and possibly caustic degradation to mattress components. They are excluded from the current project because their rate of occurrence seems less frequent than a typical exposure scenario should consider.

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[1] About a third of the U.S. population (30 percent of men and 26 percent of women) reports having sex "2 or 3 times per week"; another third (36 percent of men and 37 percent of women) reports having sex "a few times a month"; the remainder report having sex "a few times a year" or less (Weis, 1997-2001).

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MEMORANDUM

DATE: December 12, 2005

TO : Treye Thomas, Ph.D. Toxicologist, Directorate for Health Sciences

THROUGH: Andrew G. Stadnik, P.E., Associate Executive Director, Directorate for Laboratory Sciences
Joel R. Recht, Ph. D., Director, Division of Chemistry (LSC)

FROM : Bharat Bhooshan, Ph. D., Chemist, LSC

SUBJECT : Vinylidene Chloride (VC) Testing in Mattress-barrier Samples

I. Introduction

The Commission is considering a rule which will require mattresses to be resistant to open-flame fires. The manufacturers can achieve this end-point by using a variety of methods, including treatment with fire-retardant chemicals. The Commission staff recognizes the need to assess any potential health effects of exposure to chemicals that may be used by mattress manufacturers in order to comply with this proposed rule.

The Commission staff has identified numerous materials that mattress manufacturers may use as a mattress fire barrier. Most of these materials have been treated with fire-retardant chemicals. LSC staff has conducted experiments to assess exposure to chemicals released by these materials under various scenarios of mattress use. One of the chemicals identified is polyvinylidene chloride (PVDC), prepared by the polymerization of vinylidene chloride (VC), that may be present in these mattress barrier materials. VC is also known as 1,1-dichloroethylene (1,1-DCE). PVDC containing materials, both non-woven and knit, may contain VC as a residual monomer. Therefore, experiments were designed to determine (1) VC content in such materials, and (2) the release of VC from these materials under some experimental conditions. Results obtained in these experiments are discussed in this report, and will be used by the Commission staff toxicologists to assess whether there are potential health risks to consumers from exposure to these materials.

II. Methods

Five mattress barrier materials were identified by the staff as products containing PVDC. Details of these materials are shown in Table 1.

A. Concentration of VC in Polyvinylidene Chloride (PVDC) Materials.

A small amount (90 – 100 mg) of each material is placed in a test tube and xylene (1.0 ml) containing the internal standard cyclohexane is added. It is left at room temperature for 48 hours; each tube is shaken two times for one minute during this holding period. The xylene solution in each tube is analyzed by injecting 1.0 µl into the Gas Chromatograph/Mass Spectrometer (GC/MS). Three standard solutions (13.2, 26.9, and 56.1 µg/g) of VC in xylene (containing the internal standard cyclohexane) are also analyzed at the same time and the data (Table 2) are used to prepare a three-point standard curve for VC. The results of analysis for the mattress barrier samples are shown in Table 3. The GC conditions were as given below-

Column	J&W DB-1, 0.25 mm ID, 30 m, 0.1µm OD
Oven Temperature	40°C (3)/@ 40°C/200°C (1)
Injection Temperature	280°C
Carrier gas	Helium, 1.0 ml/min
Injection	1.0 µl; split 1:50

B. Head Over Heels (HOH) Experiment.

CPSC staff considered this experiment as an exaggerated scenario of consumer exposure to FR chemicals from mattresses. The experiment involves placing circular pieces (diameter 2.0 inches) of mattress barrier material in a glass bottle (250 ml) containing normal saline solution (50 ml) and shaking the bottle for 30 minutes at 60 rpm in a circular motion (vertical, diameter 2 feet). The normal saline solution is removed for analysis. For each sample, the process is repeated two more times with fresh normal saline solution.

For VC analysis, 10 ml of the normal saline is placed in a test tube. One milliliter of xylene is added to the test tube and the tube is spun for one minute. The supernant xylene is analyzed for VC content by injecting 1.0 µl into the GC/MS. The results for the three extractions are combined and reported in Table 4.

III. Results & Discussion

Data in Tables 3 and 4 shows that VC could not be detected in any of the samples analyzed. This is not surprising since VC is very volatile with a boiling point of 30°C. Also, the concentration of VC in the polymer will decrease over time, due to the volatility of VC, as the material is stored and transported from PVDC producer to the mattress manufacturer to the mattress distributor/retailer. The World Health Organization published a document* titled, "1,1-Dichloroethene (Vinylidene chloride)" which states:

"PVDC copolymers containing 79–90% 1,1-DCE are used to form moisture and vapor barrier coatings and films, with applications as food packaging products. PVDC copolymers containing 10–70% 1,1-DCE are used to improve flame and ignition resistance properties in the final product. Residual 1,1-DCE in PVDC used for food packaging products typically ranges from 5 to <1 mg/kg, the limit of detection of the method. Other consumer products containing PVDC

* 1,1-Dichloroethene (Vinylidene chloride), (Concise International Chemical Assessment Document; 51), WHO, 2003.

include PVDC-latex for carpet backing (<2 mg/kg residual 1,1-DCE), PVDC-latex for Foil Scrim Kraft (<3 mg/kg residual 1,1-DCE), PVDC-latex for photographic film coating (<100 mg/kg residual 1,1-DCE), PVDC for flame retardant fibres for clothing and outdoor awnings (<100 mg/kg residual 1,1-DCE), and PVDC-fluorinated copolymers for application on textiles (<100 mg/kg residual 1,1-DCE). Further processing decreases the residual 1,1-DCE in the final consumer product."

If VC concentration is 100 ppm in PVDC during manufacture, it could easily decrease to 10 ppm at the mattress retailer. If mattress barrier material contains 10% of PVDC material, the VC level in the final barrier may be near or below 1 ppm.

The low concentration used in the standard curve is 13.24 μg/g or 13.24 ppm (Figures 1 and 2). The limit of detection is about 2.8 μg/g (Figures 3 and 4) and the instrumental limit of quantitation is about 6 ppm (or 6 ng per injection into GC/MS). The HOH experiment could not detect VC in samples with this low level of total VC concentration. Since VC was not detected in these experiments, the concentration of VC in mattress barrier samples is below 30 ppm, assuming all VC present was extracted.

IV. Conclusion

An attempt was made to determine the concentration of residual monomer vinylidene chloride (VC) in five mattress barrier materials containing polyvinylidene chloride. VC was not detected in any of the samples analyzed by GC/MS. The limit of detection is about 2.8 ppm and the limit of quantitation is about 6 ppm. Thus, the concentration of VC in mattress barrier materials is below 30 ppm.

Table 1. Mattress-barrier Samples Containing PVDC

Sample Number	Characteristics	Elements present
05-440-7801-02	Non-woven, modacrylic-visil/ Sb_2O_3, PVDC, Si	Si, Sb
05-440-7801-03	Non-woven visil/ PVDC, Si	Si
05-440-7801-04	Non-woven visil/ PVDC, Si	Si
05-440-7801-05	Visil knit/ PVDC, Si	Si
05-440-7801-06	Modacrylic knit/ Sb_2O_3, PVDC, Si	Si, Sb

Table 2. Standard Solutions Analyzed for VC

VC Standard	Ratio	VC Peak area	Cyclohexane Peak area
(µg/g)			
13.24	0.176917	861289	4868330
26.97	0.328833	1593515	4845972
56.08	0.613211	2903759	4735337

Table 3. Analyses of Vinylidene Chloride (VC) in Mattress-barrier Samples

Sample Number	Weight of sample (mg) (average of two)	VC found (µg)
05-440-7801-02	91.4	0
05-440-7801-03	102.0	0
05-440-7801-04	97.0	0
05-440-7801-05	100.4	0
05-440-7801-06	103.9	0

Table 4. Analyses of Vinylidene Chloride (VC) after HOH Experiment

Sample Number	VC found in normal saline extract (µg)
05-440-7801-02	0
05-440-7801-03	0
05-440-7801-04	0
05-440-7801-05	0
05-440-7801-06	0

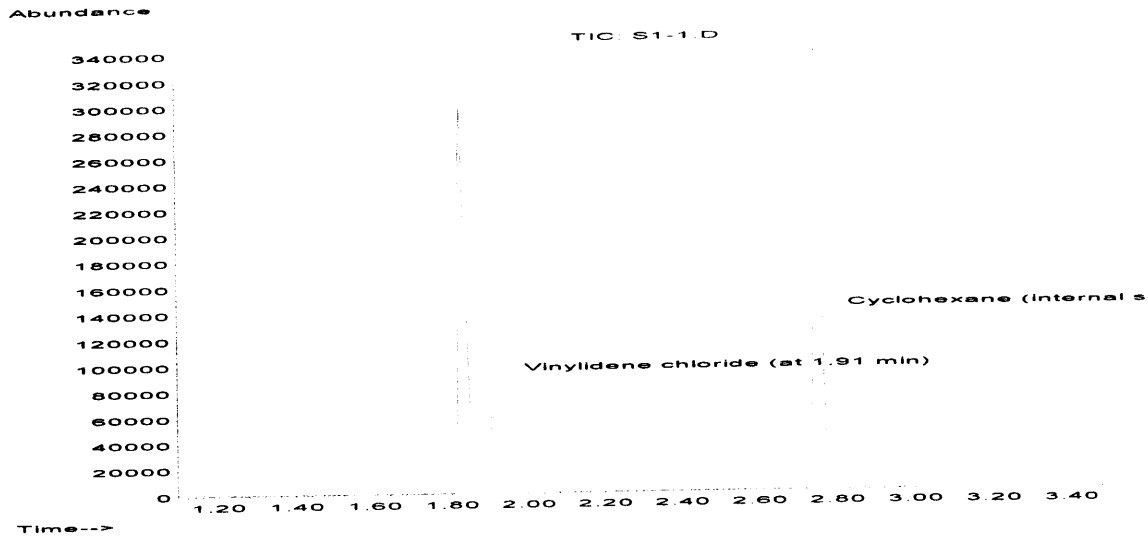

Figure 1. MS Scan for Low Vinylidene Chloride Standard Solution (13.24 ppm).

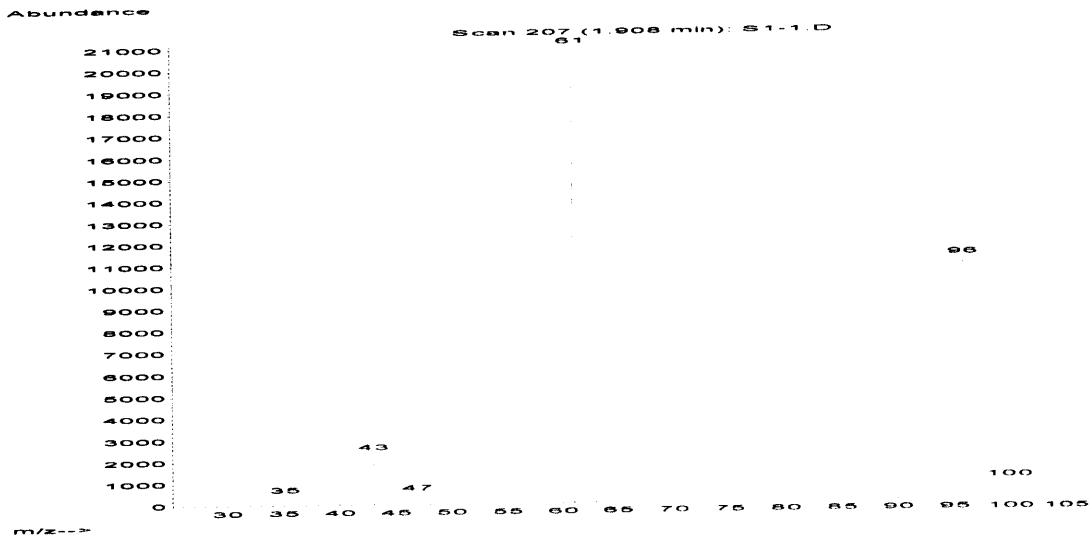

Figure 2. MS Spectra of Vinylidene Chloride.

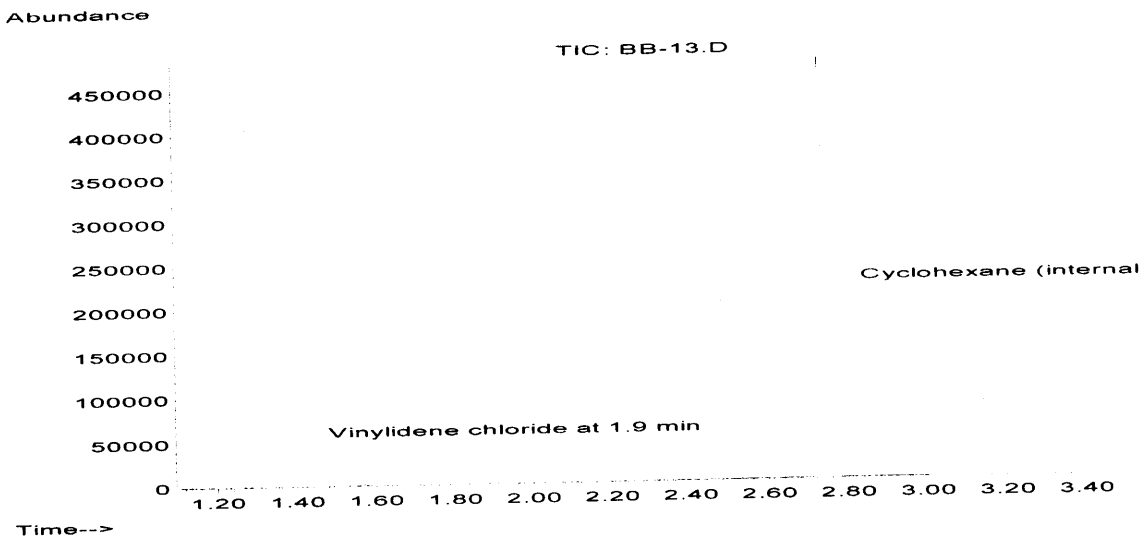

Figure 3. MS Scan for 2.8 ppm Vinylidene Chloride Solution.

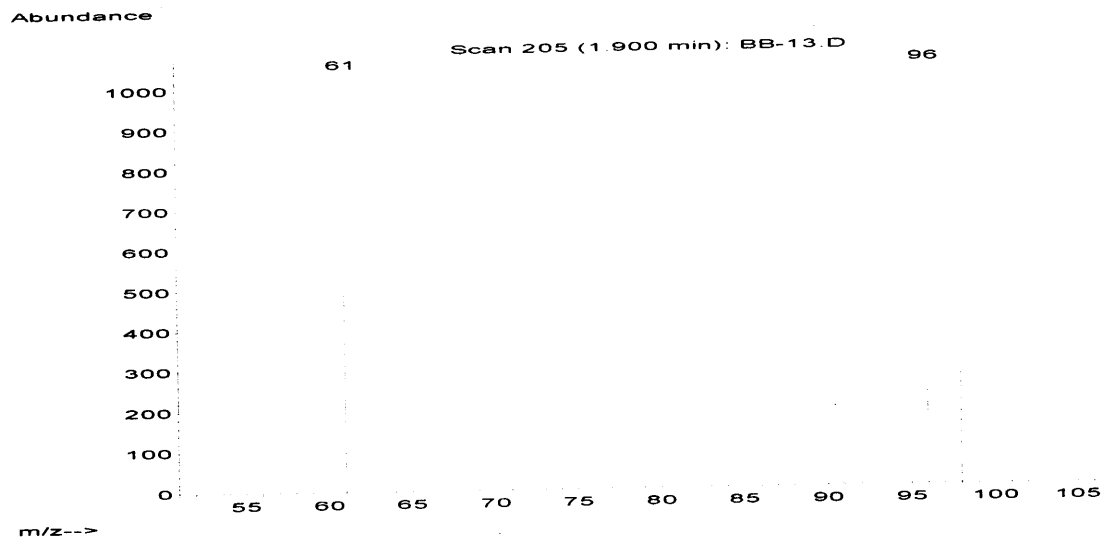

Figure 4. MS Spectra of Vinylidene Chloride (Detectable).

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THROUGH: Andrew G. Stadnik, P.E., Associate Executive Director, Directorate for Laboratory Sciences (LS)
Joel R. Recht, Ph.D., Director, Division of Chemistry (LSC)

FROM : David Cobb, Chemist, Division of Chemistry

SUBJECT : Migration of Flame Retardant Chemicals in Mattress Barriers

SUMMARY:

A variety of commercially available barriers that may be used to make mattresses compliant with the CPSC staff's draft final standard for flammability were analyzed for flame retardant chemical (FRC) content and subjected to several migration scenarios to simulate potential consumer exposure to FRC during use of the product.

1. Boric acid[1] (H_3BO_3) and melamine are very water soluble. In moisture mediated migration, the amounts of H_3BO_3 or melamine that migrate from barrier materials will be dependent on such factors as the amount of solvent (i.e sweat, urine, water) applied to the material, the rate at which it is applied, and the presence of other absorbing materials such as ticking material, sheets, mattress covers and clothing. The test condition for simulated dermal transfer of H_3BO_3 which most closely simulated actual use was done using a mini mattress mockup and resulted in a maximum of 93.6 $\mu g/cm^2$ of H_3BO_3 migration to the filter paper.

2. The amount of H_3BO_3 detected in the airborne samples was near or below the limit of detection (LOD) for most of the unaged samples. H_3BO_3 was detected with a maximum level of 39.5 μg over 28 hours in the airborne samples of the aged mockups. The aging condition of 90°C and 85% humidity results in a large amount of moisture in the chamber, and thus on the mockup. These extremely moist conditions allow for the migration of H_3BO_3 from the barrier material to the ticking material, but these high temperature and humidity conditions would not be encountered during normal usage.

[1] In this study boric acid results are based on boron content measured and may represent multiple boron or borate sources.

3. Melamine was not detected in the barriers treated with a melamine resin. The melamine resin is made of a polymer network from a chemical reaction using melamine.

4. Antimony trioxide (Sb_2O_3) and decabromodiphenyl oxide (DBDPO) are not very water soluble and the amounts that migrated during the surface migration tests were low. The amount of Sb_2O_3 detected (based on antimony) in the airborne samples for all of the aged and unaged samples was near or below the LOD, with a maximum of 0.4μg over a 28 hour period.

5. Vinylidene Chloride (VC) monomer was below the detection limit of 30 ppm for all of the barriers[2].

BACKGROUND:

LSC was requested to determine chemical load and exposure potential of FRCs that are found in barrier materials that may be used in mattress construction. A range of commercially available barrier materials were tested. The FRCs used to treat the barriers include melamine, boric acid (H_3BO_3), antimony trioxide (Sb_2O_3), polyvinylidene chloride (PVDC), and decabromo diphenyl oxide (DBDPO), ammonium polyphosphate (APP) and silicon (Si) based compounds. Barriers containing PVDC were analyzed for VC monomer content. No exposure study was done at this point for Si compounds as there was no indication of the presence of crystalline silica. Only a limited study of APP migration was included in this work.

This study can be broken down into 3 phases. Phase 1 involved determining the total FRC load in the barrier materials. Phase 2 involved migration tests to determine potential dermal exposure. Phase 3 involved durability, aging and airborne sampling of mattress mockups with FRC containing barriers under conditions simulating use.

PHASE 1 BARRIER SAMPLE ID AND FRC LOAD

Information on the various barrier samples along with the average chemical load found by LSC are contained in Table 1. The FRC percentages listed in Table 1 are the average from 5 replicates.

Total H_3BO_3 chemical load was determined by digesting 50-100 milligram (mg) aliquots of the barrier samples in 2 milliliters (ml) of nitric acid under refluxing condtions on a hot plate for 4-6 hours, diluting to 10 ml with deionized water, and analyzing using inductively coupled plasma atomic emission spectroscopy (ICP) to determine boron (B) content.

Total Sb_2O_3 chemical load was determined by extracting 50-100 mg aliquots of the barrier samples in 3 ml of hydrochloric acid under refluxing condtions on a hot plate for 4-6 hours, diluting to 10 ml with deionized water, and analyzing using ICP to determine antimony (Sb) content.

[2] CPSC Memo from Bhooshan, Bharat June 2005

Table 1. Barrier ID and FRC Load							
Barrier ID	**Type/FRC content**	**Density (mg/cm^2)**	**FRC Percentage (%) Determined by CPSC**				
			H_3BO_3	**Sb_2O_3**	**DBDPO**	**Melamine**	**VC**
1	Cotton Batting/ H_3BO_3, Sb_2O_3	34.4	7.5	2.4			
2	Nonwoven modacrylic-visil/ Sb_2O_3, PVDC, Si	15.4		3.8			ND
3	Nonwoven visil/ Si, PVDC	21.4					ND
4	Nonwoven visil/ Si, PVDC	21.7					ND
5	Visil knit/ Si, PVDC	21.6					ND
6	Modacrylic knit/ Sb_2O_3, Si, PVDC	16.2		4.5			ND
7	Coated fiberglass/ DBDPO	17.4			7.5		
9	Coated Foam/ Melamine, H_3BO_3, Sb_2O_3	61.5	4.1	4.1		4.9	
10	Coated Poly-Cotton Ticking/ Melamine, H_3BO_3, Sb_2O_3	32.1	3.5	2.7		2.9	
11	Coated Poly-Cotton/ Melamine, H_3BO_3, Sb_2O_3	21.7	4.0	3.1		4.1	
12	Coated Knit/ Melamine, H_3BO_3, Sb_2O_3	28.1	4.0	4.4		6.6	
13	Melamine Resin					ND	
14	Melamine Resin					ND	
15	Melamine Resin					ND	
16	Melamine Resin					ND	
17	Melamine Resin					ND	
18	Melamine Resin					ND	
19	Melamine Resin					ND	

Note: ND – not detected. The limit of detection (LOD) for VC in the barrier samples is 30 ppm. The LOD for melamine in the barrier samples is 0.002%.

Total DBDPO chemical load was determined by extracting 50-60 mg aliquots of the barrier sample in 5 ml of dioxane, and analyzing using high pressure liquid chromatography (HPLC) to determine DBDPO content. The HPLC conditions used are as follows:

Column: Waters Symmetry 3.5μm C18, 2.1mm x 100 mm
Eluant: 100% Acetonitrile
Flow: 0.4 ml/min
Detector: Photodiode Array (UV-Vis)
Wavelength of maximum absorbance: 228 nm
Sample volume injected: 5μl

The peak retention time for DBDPO occurred at 5.8 minutes. Calculation of DBDPO was done by measuring the peak areas of standards and samples at this retention time, and doing a linear regression of peak area versus amount of DBDPO injected.

Total melamine chemical load was determined by extracting 50-100 mg aliquots of the barrier samples in 10 ml of deionized water on a water bath at 60°C overnight, and analyzing using HPLC. Seven barrier samples containing melamine resin, which is based on melamine and formaldehyde reaction products, were also screened for total melamine content. Melamine was not detected in any of the melamine resin barriers. The HPLC conditions used are as follows:

Column: Waters Sperisorb 5μm NH_2, 4.6mm x 250 mm
Eluant: 95% acetonitrile, 5% water
Flow: 1.0 ml/min
Detector: Photodiode Array (UV-Vis)
Wavelength of maximum absorbance: 207 nm
Sample volume injected: 5μl

The peak for melamine occurred at about 10.2 minutes. Calculation of melamine was done by measuring the peak areas of standards and samples at this retention time, and doing a linear regression of peak area versus amount of melamine injected.

Total VC chemical load was determined by extracting 90-100 mg samples with 1.0 ml of xylene at room temperature for 48 hours, and analyzing using gas chromatography mass spectrometry (GC-MS). Residual VC was not detected in any of the sample aliquots. VC is a monomer that polymerizes to polyvinylidene chloride during the manufacturing process of the FRC treated barrier materials. VC is a very unstable chemical that self polymerizes, and is very volatile with a boiling point of 31.7°C. Any VC monomer remaining on the barrier material after the manufacturing process would quickly self polymerize or evaporate, thus it is not surprising that VC was not detected in barrier samples.

PHASE 2 MIGRATION TESTS

Head over Heels (HOH) – These studies were conducted to simulate an aggressive exposure scenario. This test serves as an exaggerated scenario of consumer exposure and the migration of FRC is much higher than would likely occur for real barrier materials during anticipated use. A saline solution of 0.9% sodium chloride was used as a surrogate for saliva. A small circular piece of barrier material, 5.5 centimeter (cm) in diameter, was weighed and then placed in a screw cap bottle (6.4 cm x 14 cm) containing 25 ml of saline solution and shaken in a vertical circular motion (12 inch diameter) at 60 rpm for 30 minutes. The liquid saline extract was removed and saved for analysis. A fresh 25 ml of saline was added to the bottle containing the

barrier sample, and the bottle was shaken as above for 30 minutes. The saline extract was removed and saved for analysis. The HOH procedure was repeated a 3rd time. Each separate solution obtained from these shakings was analyzed for Sb and B by ICP. The solution extracts obtained from melamine treated barriers were analyzed for melamine by HPLC. The solution extracts obtained for the DBDPO treated barrier were extracted with dioxane and analyzed for DBDPO by HPLC. The solution extracts obtained for the PVDC treated barrier were extracted with xylene and analyzed for VC by GC-MS. Four replicate HOH tests were done for each barrier sample. The HOH results are contained in Tables 2 and 3 and are the average result and standard deviation of the 4 replicates. VC was not detected. Table 3 gives the percentage of FRC extracted compared to total FRC load determined for that barrier, given the size of the sample extracted.

Table 2 Head over Heels Extraction

Average FR Chemical Extracted (mg/cm^2)

Barrier	Extraction	H_3BO_3	Sb_2O_3	DBDPO	Melamine
1	1	2.014			
	2	0.528			
	3	0.184			
	total (stdev of 4 replicates total)	**2.725** (0.451)			
2	1		0.0004		
	2		0.0002		
	3		0.0001		
	total (stdev of 4 replicates tota)l		**0.0007**(0.0001)		
6	1		0.0004		
	2		0.0004		
	3		0.0005		
	total (stdev of 4 replicates total)		**0.0014**(0.0005)		
7	1			0.008	
	2			0.006	
	3			0.001	
	Total (stdev of 4 replicates total)			**0.015**(0.012)	
9	1	2.171	0.0130		1.80
	2	0.757	0.0041		0.98
	3	0.283	0.0019		0.49
	total (stdev of 4 replicates total)	**3.212**(0.277)	**0.0189**(0.0030)		**3.28**(0.12)
10	1	0.650	0.0020		0.79
	2	0.147	0.0012		0.29
	3	0.066	0.0010		0.10
	total (stdev of 4 replicates total)	**0.862**(0.178)	**0.0041**(0.0004)		**1.18**(0.15)
11	1	0.546	0.0032		0.85
	2	0.094	0.0017		0.19
	3	0.056	0.0010		0.09
	total (stdev of 4 replicates total)	**0.695**(0.062)	**0.0059**(0.0014)		**1.13**(0.10)
12	1	0.661	0.0043		1.63
	2	0.140	0.0053		0.45
	3	0.074	0.0030		0.13
	total (stdev of 4 replicates total)	**0.874**(0.067)	**0.0126**(0.0013)		**2.21**(0.09)

Table 3 HOH Avg % FR Chemical Extracted from Total with stdev in ( )

Barrier	H_3BO_3	Sb_2O_3	DBDPO	Melamine
1	105.7 (17.5)			
2		0.03 (0.003)		
6		0.16 (0.054)		
7			0.98 (0.81)	
9	118.0 (10.2)	0.70 (0.11)		102.0 (1.8)
10	64.9 (13.4)	0.41 (0.04)		104.3 (10.5)
11	67.6 (6.0)	0.74 (0.18)		108.2 (3.7)
12	66.2 (5.1)	0.86 (0.09)		110.1 (2.1)

Note: Percentages are relative to the total FRC in the sample based on results from phase 1. Values in excess of 100% may be due to variability in FRC load.

Surface Migration to Filter Paper - These studies were conducted to assess potential consumer exposure to FRCs by skin contact. This phase of the study was subdivided into different portions as well. Initially all of the barriers studied were subjected to a more extreme condition of exposure. Additional surface migration tests that more closely represent potential exposure conditions were used for the two barriers with the highest boric acid content. Two reagent extract solutions were used. Artificial perspiration was one of the reagent extract solutions and contained 5.0 grams (g) of sodium chloride and 0.5 g of urea per liter. The other reagent extract solution used was artificial urine which contained 18.2 g of urea, 7.5 g of sodium chloride, 4.5 g of potassium chloride, 4.8 g of sodium phosphate, 2 g of creatinine and 50 mg of albumin per liter. In most of the experiments, a circular piece of barrier material with a 5.5 cm diameter was weighed and then placed in a 600 ml beaker. The barrier material was covered with a circular Whatman® #2 filter paper having a diameter of 5.5 cm. The filter paper and barrier material were thoroughly wetted with 2 to 4 ml of the extract reagent. The beaker was left in a hood until the filter paper and barrier material were dry (about 6-8 hours). The dry filter paper was removed and placed in a test tube for analysis for applicable FRC. Filter papers for B analysis were digested in 4 ml of nitric acid on a hot plate for 6 hours and diluted to 10 ml with deionized water prior to analysis by ICP. Filter papers for Sb analysis were extracted with 10 ml of 4N HCl for 4 hours prior to analysis by ICP. Filter papers for DBDPO analysis were extracted with 10 ml of dioxane overnight prior to analysis by HPLC. The barrier material in the beaker was covered with another filter paper and the process repeated until a total of four consecutive extractions of the same barrier sample by each reagent extract was done. The surface migration to filter paper experiment was also done with a 1 pound per square inch (psi) weight placed on the wetted filter paper and barrier material sample. The weights were stainless steel rods with a diameter of 2 inches, and weighed 3.14 lbs. Five replicate tests were done on each barrier sample using each of the reagent extracts, and both weighted and unweighted conditions. The average results of the 5 replicates are listed in Table 4.

Table 4. Surface Migration of chemical to Filter Paper

Barrier	Filter Paper Extract	Reagent Extract	No Weight Avg µg/cm² FRC (% of Available FRC extracted)			1 PSI Weight Avg µg/cm² FRC (% of Available FRC extracted)		
			H_3BO_3	Sb_2O_3	DBDPO	H_3BO_3	Sb_2O_3	DBDPO
1	1	Perspiration	24.0 (0.85)			829 (30.0)		
	2		7.8 (0.28)			528 (19.7)		
	3		19.2 (0.64)			250 (9.6)		
	4		3.8 (0.13)			155 (6.0)		
	Total		**54.7 (1.9)**			**1762 (65.3)**		
1	1	Urine	16.5 (0.55)			746 (28.7)		
	2		7.1 (0.24)			471 (16.9)		
	3		7.2 (0.24)			214 (7.8)		
	4		3.6 (0.12)			201 (7.3)		
	Total		**34.4 (1.16)**			**1633 (60.7)**		
6	1	Perspiration		0.09 (0.01)			0.29 (0.03)	
	2			0.13 (0.01)			0.32 (0.04)	
	3			0.14 (0.02)			0.33 (0.04)	
	4			0.11 (0.01)			0.41 (0.05)	
	Total			**0.47 (0.06)**			**1.35 (0.16)**	
6	1	Urine		0.12 (0.01)			0.34 (0.04)	
	2			0.17 (0.02)			0.64 (0.08)	
	3			0.22 (0.03)			0.61 (0.07)	
	4			0.23 (0.03)			0.45 (0.05)	
	Total			**0.74 (0.09)**			**2.05 (0.25)**	
7	1	Perspiration			0.05			0.12
	2				0.02			0.01
	3				0.005			0.02
	4				0.03			0.04
	Total				**0.10 (0.01)**			**0.20 (0.02)**
7	1	Urine			0.04			0.02
	2				0.01			0.03
	3				0.03			0.07
	4				0.48			0.02
	Total				**0.56 (0.06)**			**0.15 (0.01)**

Table 4. Continued						
Barrier	Filter Paper Extract	Reagent Extract	No Weight Avg µg/cm² FRC (% of Available FRC extracted)		1 PSI Weight Avg µg/cm² FRC (% of Available FRC extracted)	
			H_3BO_3	Sb_2O_3	H_3BO_3	Sb_2O_3
9	1	Perspiration	136 (4.6)	2.01 (0.07)	360 (12.0)	5.47 (0.18)
	2		188 (6.3)	2.51 (0.08)	325 (10.8)	2.98 (0.10)
	3		172 (5.8)	1.89 (0.06)	250 (8.3)	1.64 (0.05)
	4		80.0 (2.7)	0.67 (0.02)	215 (7.2)	1.19 (0.04)
	Total		**577 (19.4)**	**7.08 (0.24**	**1148 (38.3)**	**11.28 (0.37)**
9	1	Urine	91.1 (3.3)	1.14 (0.04)	320 (10.7)	4.11 (0.14)
	2		173 (6.3)	1.98 (0.07)	332 (11.1)	2.45 (0.08)
	3		173 (6.2)	1.76 (0.06)	276 (9.2)	1.27 (0.04)
	4		135 (4.9)	1.10 (0.04)	334 (11.1)	0.87 (0.03)
	Total		**573 (20.7)**	**5.97 (0.22)**	**1263 (42.1)**	**8.69 (0.29)**
11	1	Perspiration	117 (6.2)	1.69 (0.22)	256 (25.0)	8.92 (1.16)
	2		88.0 (4.6)	0.67 (0.09)	167 (16.2)	2.25 (0.29)
	3		45.9 (2.4)	0.24 (0.03)	83.9 (8.2)	0.95 (0.12)
	4		34.8 (1.8)	0.17 (0.02)	74.6 (7.3)	0.57 (0.07)
	Total		**286 (15.1)**	**2.77 (0.36)**	**581 (56.7)**	**15.1 (1.64)**
11	1	Urine	118 (6.2)	3.79 (0.49)	232 (23.5)	9.76 (1.29)
	2		86.7 (4.5)	0.52 (0.06)	201 (20.4)	1.14 (0.15)
	3		72.5 (3.8)	0.31 (0.04)	146 (14.8)	0.65 (0.08)
	4		72.2 (3.8)	0.31 (0.04)	105 (10.6)	0.58 (0.08)
	Total		**350 (18.2)**	**4.93 (0.63)**	**684 (69.3)**	**12.1 (1.60)**

Additional Surface Migration Tests on Barriers treated with Boric Acid – Barrier materials treated with boric acid were subjected to additional surface migration tests that more closely represent mattress construction. Additional beaker tests were done in which ticking material and standard sheet material were placed between barrier material and filter paper. The materials were wetted with 2 ml of simulated perspiration and the 1 psi wt was placed on top of the filter paper. The three additional beaker study scenarios were as follows, and five replicates were done for each scenario:

1. Barrier material covered with ticking, filter paper placed on top, all wetted with 2 ml of simulated perspiration
2. Barrier material covered with ticking, wetted with 2 ml of simulated perspiration, dry filter paper place on top
3. Barrier material covered with ticking and standard sheet, filter paper placed on top, all wetted with 2 ml of simulated perspiration

The results of the additional beaker tests are contained in Table 5. Surface migration tests were also done on miniature mattress mockups that consisted of 9"x 9" x 1/2" plywood covered with 9" x 9" x 3" slab of non-FRC treated foam, covered with ticking material and standard sheet.

This set of experiments more closely mimics actual consumer exposure. The mockups were wetted with 25 ml of simulated perspiration, 2 dry filter papers were placed on top, and the 1 psi weights were placed on the filter papers for 6 hours. The weights were removed and the filter papers were placed in test tube for applicable FRC analysis. A photograph of the miniature mockup surface migration test is contained in Figure 1. The results of the mockup migration test are contained in Table 6.

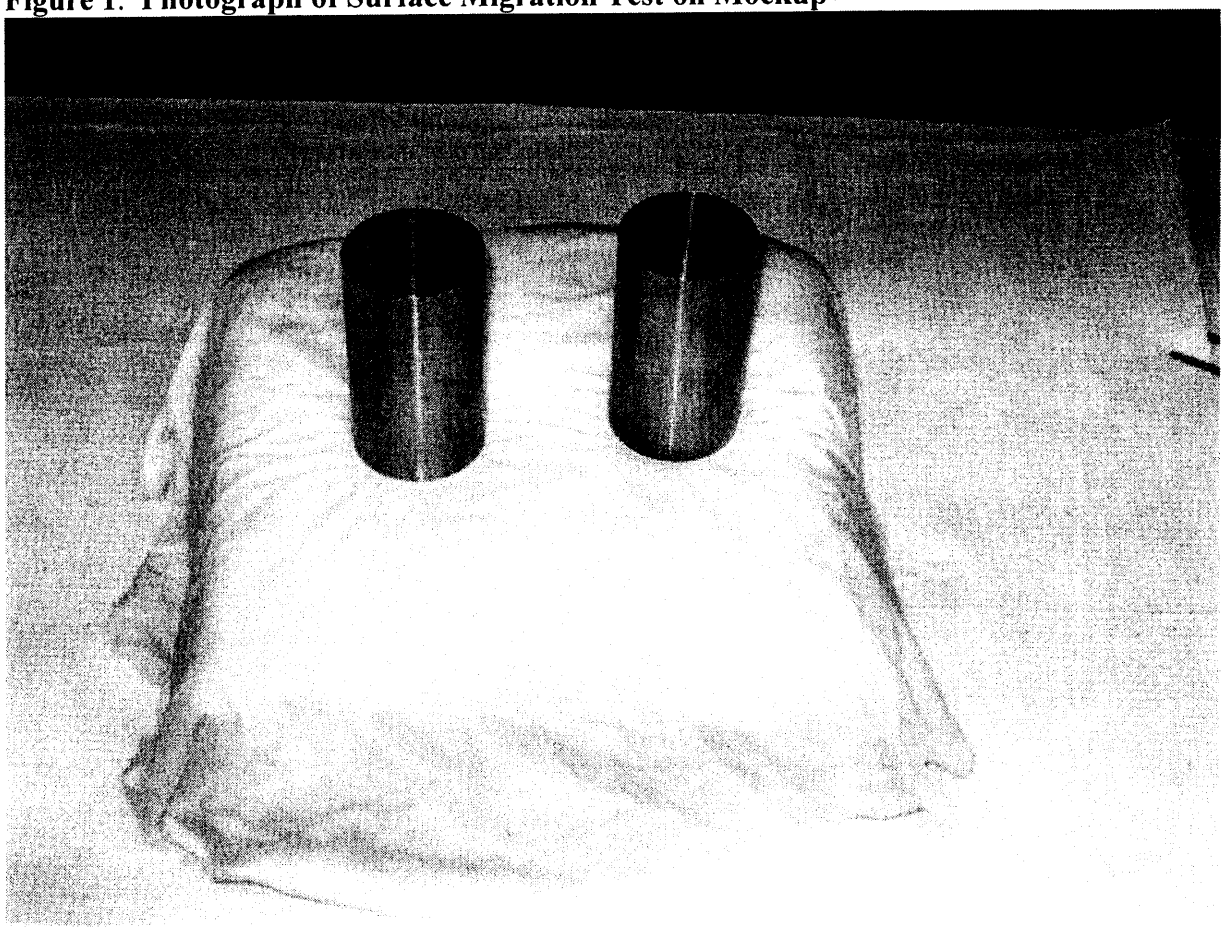
Table 5. Effects of Ticking, Sheet , and Filter Paper Wetness on H_3BO_3 Surface Migration

Barrier	Scenario Condition	Filter Paper Extract	Avg µg/cm^2 H_3BO_3	% H_3BO_3 Extracted of Total Load
1	Barrier, Ticking, Filter Paper – All Wet	1	444	15.0
		2	218	7.2
		3	166	5.6
		4	92	3.1
		Total	**920**	**31.0**
1	Barrier, Ticking – Wet, Dry Filter Paper on top	1	484	17.9
		2	276	10.2
		3	190	7.1
		4	129	4.8
		Total	**1078**	**40.0**
1	Barrier, Ticking, Sheet, Filter Paper – All Wet	1	123	5.6
		2	83	3.6
		3	78	3.4
		4	86	3.9
		Total	**370**	**16.5**
9	Barrier, Ticking, Filter Paper – All Wet	1	350	12.8
		2	192	7.0
		3	145	5.4
		4	102	3.9
		Total	**789**	**29.1**
9	Barrier, Ticking – Wet, Dry Filter Paper on top	1	277	9.4
		2	313	10.6
		3	200	6.8
		4	229	7.8
		Total	**1018**	**34.6**
9	Barrier, Ticking, Sheet, Filter Paper – All Wet	1	138	4.6
		2	162	5.5
		3	173	5.9
		4	213	7.2
		Total	**687**	**23.0**

Table 6. Miniature Mockup Surface Migration Tests

Barrier	Filter Paper Extract	Avg µg/cm^2 H_3BO_3
1	1	10.7
	2	9.3
	3	6.2
	4	5.3
	Total	**31.5**
9	1	32.2
	2	22.6
	3	26.4
	4	12.4
	Total	**93.6**
1	Sheet	38.6
	Ticking	1.6
9	Sheet	22.5
	Ticking	2.5

Figure 1. Photograph of Surface Migration Test on Mockup



Surface Migration Tests on a Mattresses with Barriers treated with Boric Acid- A twin mattress with a barrier treated with boric acid was subjected to similar surface migration test that was done on the miniature mattress mockups. The mattress was wetted in one section with 25 ml of simulated perspiration, and in another section with 25 ml of simulated urine. Two dry filter papers were placed on top in each section, and the 1 psi weights were placed on the filter papers. The 1 psi weight was immediately removed from one filter paper from each section once the filter paper was thoroughly wetted. The other filter papers had the weights in place for 6 hours. The weight was removed, and then the filter papers were allowed to dry in place for 2 hours. The dry filter papers were placed in separate test tubes for boron analysis. The results of the mattress migration test are contained in Table 7a.

Surface Migration Tests on a Mattress with a Barrier treated with Ammonium Polyphosphate- A twin mattress with a barrier treated with ammonium polyphosphate (APP) was subjected to a similar surface migration test as the boric-acid treated mattress above. The mattress was wetted in one section with 25 ml of simulated perspiration. One dry filter paper was placed on top, and a 1 psi weight was placed on the filter paper. The filter paper had the weight in place for 6 hours. The weight was removed, and then the filter papers were allowed to dry in place for 2 hours. The dry filter papers were placed in separate test tubes for phosphorus analysis. The results of the mattress migration test are contained in Table 7b.

Table 7a. Mattress Surface Migration Tests for Boric Acid

Reagent Extract	**Filter Paper Extract**	**1 psi wt in place for 6 hours $\mu g/cm^2$ H_3BO_3**	**1 psi wt removed $\mu g/cm^2$ H_3BO_3**
Perspiration	1	74.8	45.5
	2	33.3	23.9
	3	22.4	13.3
	4	22.5	16.6
	Total	153.0	99.3
Urine	1	90.4	20.3
	2	42.1	31.1
	3	28.5	14.1
	4	28.8	10.6
	Total	189.7	76.1

Table 7b. Mattress Surface Migration Tests for Ammonium Polyphosphate

Reagent Extract	**Filter Paper Extract**	**1 psi wt in place for 6 hours $\mu g/cm^2$ Phosphorus**
Perspiration	1	14.32
	2	2.13
	3	0.48
	4	0.26
	Total	17.19

PHASE 3 DURABILITY – AIRBORNE TESTS

Miniature barrier mattress mockups as described previously, but with no sheet over the ticking, were subjected to continuous impaction while sampling the air above the mockups for

FRC. Photographs of the barrier mockup impactor test setup are contained in figure 2a and 2b. The impactor was constructed by Directorate of Laboratory Sciences, Division Mechanical Engineering staff and consisted of an air piston driven plastic concave head with a diameter of 4". The impactor conditions used were as follows:

1. 100,000 cycles
2. 1 second per cycle, 0.5 seconds in each direction
3. 3 psi impact force, stroke length set so that impactor head did not bottom out during cycle

The mockup impactor tests were done inside an inflatable glove bag placed over a frame. The frame had dimensions of 13.5" x 20" x 27". The bag was sealed during impaction testing. The air sampling was done using calibrated sampling pumps to draw a known volume of air through membrane filter contained in a styrene cassette. The sampling was done using aluminum cyclone samplers. This sampling technique collects respirable size material. There were 4 sampling sites within the frame. The air sampling conditions were as follows:

1. 2 liters per minute
2. 35 mm diameter 5μ polyvinyl chloride (PVC) filter for B sampling
3. 35 mm diameter, 0.8μ cellulose filter for Sb sampling
4. 35 mm diameter, glass fiber filter for DBDPO sampling

Filters collected from the air sampling for B and Sb were digested in nitric acid, sulfuric acid, hydrogen peroxide, and hydrochloric acid following procedures outlined in US Occupational Safety and Health Administration (OSHA) method for *Metal and Metalloid Particulates in Workplace Atmospheres (ICP Analysis)*. The digested filters were analyzed for B and Sb using ICP. Most of the analysis results were below the method detection limit (MDL). The MDL for B is 0.15 μg and Sb is 0.3μg. In an attempt to see measurable results, mockup #3 constructed with barrier 9, was tested without ticking material, and mockup #3 constructed with barrier 1 was wetted with 100 ml of deionized water and allowed to dry in fume hood prior to impaction and airborne sampling.

Circular Whatman® #2 filter papers with 5.5 cm diameter and Ghost™ Wipes were placed inside the bottom of the impaction test frame near the mockups during testing. The filter papers and wipes were placed close to the mockups to collect particles ejected from the mockups during impaction that would be too large or too small to be collected on the filter cassettes using the aluminum cyclones. The filter papers and wipes were digested in nitric acid, sulfuric acid, hydrogen peroxide, and hydrochloric acid and analyzed for B and Sb using ICP.

Filters collected from the air sampling for DBDPO were extracted with acetonitrile using Soxhlet extractors. The extract was transferred to beakers and allowed to evaporate. Two ml of acetonitrile was added to the beakers to dissolve any DBDPO residue, and the extract was analyzed using HPLC. The MDL for DBDPO is 0.2μg.

AGING

Some miniature barrier mattress mockups were also subjected to aging prior to impaction and airborne sampling. The aging conditions were as follows:

Temperature – 90°C
Humidity – 85%
Time – 96 hours

After the aging, the mockups were conditioned to room temperature and humidity for 24 hours prior to conducting impaction and airborne sampling. The impaction and airborne sampling conditions were the same as stated previously. The results of airborne sampling on the aged and unaged mockups are contained in Table 8.

Figure 2a. Photograph of Impaction-Airborne Sampling

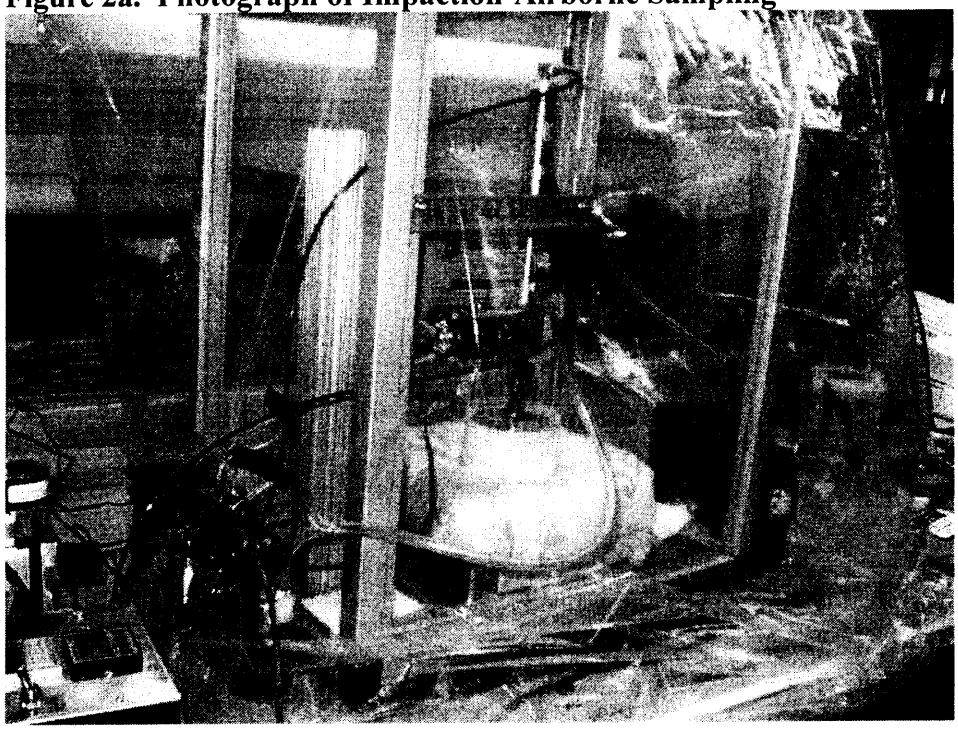


Figure 2b. Photograph of Impaction Tester

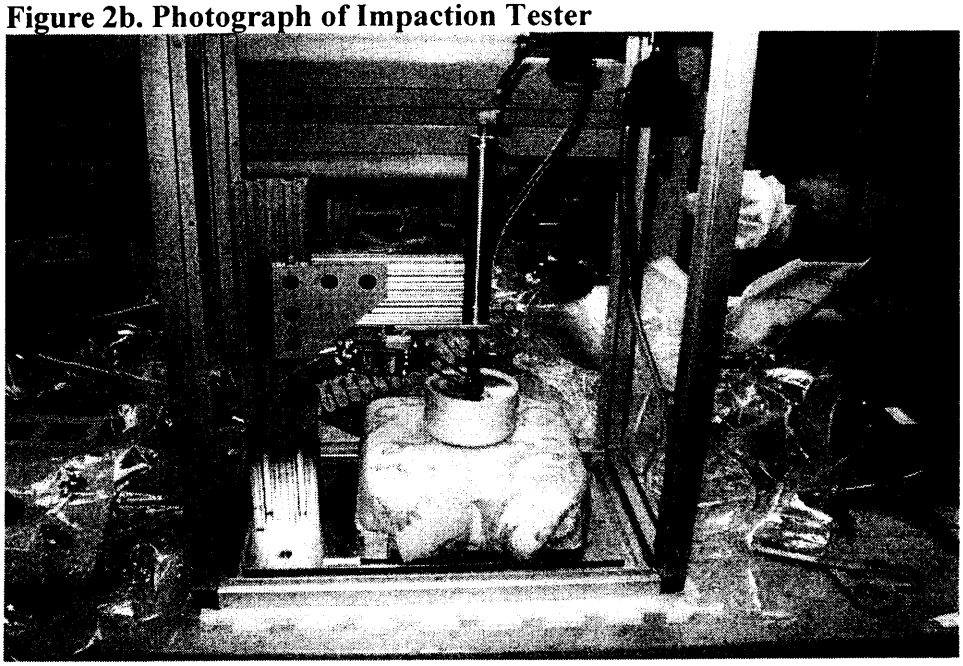


Table 8. Airborne Sample Results

Barrier ID	Mockup ID	Filter ID and (Type)	Time (hrs)	Air Volume (l)	H_3BO_3 µg	Sb_2O_3 µg
1	1 (Unaged)	1 (PVC)	4	480	<0.9	
		2 (PVC)	4	480	<0.9	
		1 (PVC)	24	2880	<0.9	
		2 (PVC)	24	2880	<0.9	
		3 (PVC)	28	3360	<0.9	
		4 (PVC)	28	3360	<0.9	
1	2 (Unaged)	1 (PVC)	6	720	<0.9	
		2 (PVC)	6	720	<0.9	
		1 (PVC)	22	2640	<0.9	
		2 (PVC)	22	2640	<0.9	
		3 (PVC)	28	3360	<0.9	
		4 (PVC)	28	3360	3.4	
		5 (Whatman®)	28	NA	130.5	
		6(Whatman®)	28	NA	68.7	
1	3 (wetted)	1 (PVC)	28	3360	3.4	
		2 (PVC)	28	3360	5.2	
		3 (PVC)	28	3360	4.6	
		4 (PVC)	28	3360	4.6	
		5 (Whatman®)	28	NA	203.7	
		6(Whatman®)	28	NA	190.6	
		* GW Impact	28	NA	286.7	
		* GW Frame	28	NA	171.7	
1	4 (Aged)	1 (PVC)	6	720	3.4	
		1 (PVC)	22	2640	5.2	
		2 (PVC)	28	3360	7.7	
		3 (CE)	6	720	<0.9	
		3 (CE)	22	2640	1.7	
		4 (CE)	28	3360	6.9	
		5 Ghost™Wipe	28	NA	39.5	
		6 Ghost™Wipe	28	NA	36.1	
1	5 (Aged)	1 (PVC)	13	1560	6.9	
		1 (PVC)	15	1800	6.9	
		2 (PVC)	28	3360	5.2	
		3 (CE)	13	1560	6.9	
		3 (CE)	15	1800	3.4	
		4 (CE)	28	3360	5.2	
		5 Ghost™Wipe	28	NA	53.2	
		6 Ghost™Wipe	28	NA	105.6	

- GW – The impactor and frame were wiped with Ghost™Wipe after test to determine any residual boron on parts after impaction test

Table 7. Continued						
Barrier ID	**Mockup ID**	**Filter ID and (Type)**	**Time (hrs)**	**Air Volume (l)**	**H_3BO_3 µg**	**Sb_2O_3 µg**
9	1 (Unaged)	1 (PVC)	28	3360	0.9	
		2 (PVC)	28	3360	<0.9	
		3 (CE)	28	3360		<0.3
		4 (CE)	28	3360		<0.3
		5 (Whatman®)	28		15.5	0.4
		6(Whatman®)	28		10.3	1.7
9	2 (Unaged)	1 (PVC)	6	720	<0.9	
		1 (PVC)	22	2640	<0.9	
		2 (PVC)	28	3360	<0.9	
		3 (CE)	6	720	1.7	<0.3
		3 (CE)	22	2640	7.7	<0.3
		4 (CE)	28	3360	8.6	<0.3
		5 (Whatman®)	28	NA	<0.9	<0.3
		6 (Whatman®)	28	NA	<0.9	<0.3
9	3 No Ticking	1 (PVC)	28	3360	<0.9	
		2 (PVC)	28	3360	<0.9	
		3 (CE)	28	3360		0.4
		4 (CE)	28	3360		<0.3
		5 (Whatman®)	28	NA	56.7	0.4
		6 (Whatman®)	28	NA	32.6	<0.3
9	4 (Aged)	1 (PVC)	8	960	2.6	
		1 (PVC)	20	2400	1.7	
		2 (PVC)	28	3360	1.7	
		3 (CE)	8	960	4.3	<0.3
		3 (CE)	20	2400	13.7	<0.3
		4 (CE)	28	3360	18.0	<0.3
		5 (Whatman®)	28	NA	77.3	<0.3
		6 (Whatman®)	28	NA	81.3	<0.3
9	5 (Aged)	1 (PVC)	28	3360	2.6	
		2 (PVC)	28	3360	4.3	
		3 (CE)	28	3360	25.2	<0.3
		4 (CE)	28	3360	39.5	<0.3
		5 Ghost™Wipe	28	NA	1665	
		* GW Impactor	28	NA	152.2	
Barrier ID	**Mockup ID**	**Filter ID and (Type)**	**Time (hrs)**	**Air Volume (l)**	**DBDPO µg**	
7	2 Unaged	1 glass fiber	28	3360	0.4	
		2 glass fiber	28	3360	<0.2	
		3 glass fiber	28	3360	<0.2	
		4 glass fiber	28	3360	<0.2	
		5 (Whatman®)	28	NA	<0.2	