

# **Boron Toxicity -The Facts**

**The following comes from US Borax's Environmental Health and Safety Group.**

1. Borates are safe in consumer products such as futon, mattresses and upholstered furniture. How can we make this statement?

2. This safety is a function of low intrinsic toxicity and limited exposure

The values I am presenting (see below) are the NOAELs, which stands for No Adverse Effects Level. This is the highest dose used in laboratory studies in which exposed animals showed no adverse effects. Above this dose, animals may exhibit effects.

But this endpoint (**54.8 mg boric acid/kg/day, showing no effects**) is specific to pregnant rats, so the relevant human equivalent is stated as follows for males & females to reach the equivalent no effects dose in laboratory rats. Thus for men it would be 7.0 grams and women 3.3 grams of boric acid per day based on the body weight of 70 kg for men and 60 kg for women.

And please also keep in mind that borates are non-carcinogenic.

This level of exposure is not attainable under any foreseeable circumstance, and is particularly unachievable from the use of boric acid in sleep products. But let me explain further. There are at least three issues before the sleep industry where it concerns boric acid treated cotton batting.

Boric acid must be internalized via dermal absorption, inhalation and ingestion.

Let's have a closer look at this topic.

**Ingestion** – Should some one ingest boric acid approximately 95% would be excreted in 96 hours and remaining portion in another 96 hours. Borates cannot be retained within the fatty tissues of humans.

**Dermal absorption** is out because boric acid is basically not absorbed across intact skin and is not a factor in your industry's use.

**Inhalation** is out because it would necessitate an unattainable concentration of suspended boric acid in the air, (i.e., greater than 490 mg/m<sup>3</sup>), which is 50 times higher than the concentrations observed in boric acid processing plants. That means for example were US Borax manufactures boric acid.

**Bottom line: Toxic doses to humans are unattainable from use of boric acid in mattresses, futons and upholstered furniture.**

Rio Tinto Borax has conducted toxicological research that has addressed human health issues for the last 30 years. This is now apart of their Sustainable Development program.

But since some have questioned the toxicity of borates and in particular boric acid we should also address Boron Nutrition. Boron is an essential micronutrient and an integral part of a plant's life cycle and this is also true we are finding for humans as well.

While it has not been proven that Boron is needed for humans to live, there is almost universal agreement in the scientific community, including the World Health Organization that boron is nutritionally important to maintain optimal human health.

You most likely had a little boron in your diet if you had some fruits or vegetables with your meal during your visit to Stamford, Connecticut today.

### **Came From Slide**

#### **•The Animal Factor No Observable Adverse Effect Level (NOAEL) Studies**

–Rats - 54.8 mg boric acid/kg/day, showed no effects from boric acid.

#### **•The Human Factor**

–Acute Toxicity:

•Oral LD<sub>50</sub> 2000 - 4000 mg B/kg

–Chronic Toxicity:

#### **Reproductive Effects**

–No effects observed at concentrations  $\geq 100$  mg BA/kg/day

–Equivalent dose for 70 kg man: 7.0 g BA/day

#### **Developmental Effects:**

–No effects observed at concentrations  $\geq 54.8$  mg BA/kg/day

–Equivalent dose for 60 kg woman: 3.3 g BA/day

# **Risk Assessment of Mattresses with Borate-Treated Cotton Batting Before and After the Roller Test**

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## ***Executive Summary***

Borate treatment of cotton batting is designed to provide flame retardant properties to mattresses, creating a safer and more fire-resistant mattress. A human health risk assessment was conducted on such mattresses based on the results of wipe testing for boron on the mattress surface. This study differed from previous studies since the mattresses were subjected to the ASTM hexagonal roller test (rollator) to simulate 10 years of aging (100,000 cycles).

Stork Twin Cities Testing Corporation, an independent testing laboratory, conducted the roller test and the wipe samples. Three mattresses (two treated and one untreated) were evaluated. Six wipe samples were collected on each mattress after 0, 5000, 50,000 and 100,000 cycles of the roller test. The analytical testing was performed by West Coast Analytical Services.

The results of the wipe tests confirm that the boron in borate-treated mattresses is not fugitive, since only trace amounts of boron were found on the mattress surface. The wipe test results tended to rise slightly during the course of the roller test compared to the pretest results. After 100,000 cycles, the average and highest surface concentration of boron inside the roller area among borate-treated mattresses was 0.34 and 0.59 micrograms of boron per square centimeter, respectively; outside the roller area, the average and highest surface concentration of boron among borate-treated mattresses was 0.23 and 0.33 micrograms of boron per square centimeter, respectively. In general, the concentration of boron on the mattress surface was about one order of magnitude higher for mattresses with borate-treated cotton batting ("borate-treated mattresses") than for mattresses without borate-treated cotton batting.

Conservative estimates of exposure to boron from sleeping on borate-treated mattresses show negligible exposure for both adults and children. These estimates were made by making a number of conservative assumptions about exposure. For example, it was assumed that consumers sleep naked on bare mattresses with no sheets or mattress pad. All exposure estimates for tested mattresses are far below regulatory guidelines and standards for boron established by the Consumer Product Safety Commission, the U.S. Environmental Protection Agency, and the National Academy of Sciences Food and Nutrition Board. In fact, daily dietary intake provides greater exposure to boron than does sleeping on a borate-treated mattress – by orders of magnitude. For example, a single 6-ounce serving of grape juice contains 622 micrograms of boron, which is about 48-345 times the conservatively estimated exposure to boron from an adult sleeping on a bare borate-treated mattress. Toddlers will receive about 5-34 times more boron in their diet than the conservatively estimated exposure to boron from sleeping on a borate-treated mattress.

In summary, the use of borate-treated cotton batting in mattresses, even after 10 years of simulated use, poses no significant risk to human health. Exposure to boron resulting from sleeping on these mattresses is negligible and of no toxicological concern. In fact, a person is expected to receive more exposure to boric acid by eating fruits and vegetables than by sleeping on a treated mattress.

## ***Introduction and Background***

Jones Fiber Products asked me to evaluate the safety of mattresses containing borate-treated cotton batting before and after being subjected to a roller test. The borate treatment is designed to provide flame retardant properties to mattresses, creating a safer and more fire-resistant mattress. The purpose of this study is to assess the safety of mattresses (treated and untreated) before and after simulating 10 years of use.

An earlier study demonstrated the safety of borate-treated cotton batting by testing mattresses in a retail showroom, when the mattress is relatively new.<sup>1</sup> In comparison, the current study evaluates mattresses which have undergone the ATSM hexagonal roller test designed to simulate 10 years of mattress use.

Boron (B) is the fifth element in the periodic chart, and it is widely distributed in nature in the form of boric acid and borates. Boron is found in soils, rocks, surface and ocean waters, and in the atmosphere. In the environment, boron combines with oxygen to produce boric acid and borates. In biological systems at physiological pH, boric acid is the predominant species present regardless of whether boric acid or borates are the source of exposure to boron.<sup>2</sup>

For most people in the U.S., diet is the largest source of exposure to boric acid and borates (Coughlin, 1998; Meacham and Hunt, 1998; Rainey and Nyquist, 1998). Since the 1920s, boron in the form of boric acid or borates has been recognized as an essential plant micronutrient. It is vital for the growth and viability of plants. Accordingly, plant-derived foods contain significant amounts of boron. Healthy diets with an abundance of fruits, vegetables, and nuts deliver relatively large amounts of boron. In comparison, fatty foods are relatively low in boron. The ten foods with the highest concentration of boron are: avocado, peanut butter, peanuts, prune juice, grape juice, chocolate powder, wine, pecans, granola raisin cereal, and raisin bran cereal (Meacham and Hunt, 1998). However, because they are consumed in greater quantity, the five largest sources of boron in the U.S. diet are: coffee, milk, apples, dried beans, and potatoes; together these five foods account for 27% of dietary intake of boron (Rainey et al., 1999).

Boron has been studied extensively for its nutritional importance in animals and humans. There is a growing body of evidence that boron may be an essential element in animals and humans. Many nutritionists believe that Americans would benefit from more boron in their diet, and many popular multivitamins (e.g., Centrum) intentionally add boron.

Boric acid and borates are natural substances that have been used for decades to make a variety of products. These include glassware (e.g., Pyrex cookware), ceramics, fiberglass insulation, laundry detergents (e.g., 20-Mule Team Borax), soap (e.g., Boraxo), and personal care products, such as contact lens solutions.

Because high doses of boron can cause toxicity, health risk assessments of boron have been performed in recent years by no fewer than eight well-respected regulatory and scientific organizations. These include: the Institute for Evaluating Health Risks (IEHR, 1995), European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC, 1995), International Programme for Chemical Safety (IPCS, 1998), World Health Organization (1998), National Academy of Sciences Food and Nutrition Board (NAS FNB, 2000), U.K. Expert Group on Vitamins and Minerals (UK EVM, 2002), U.S. Consumer Product Safety Commission (CPSC, 2004) and U.S. Environmental Protection Agency (US EPA, 2004). These risk assessments estimate acceptable daily intakes of boron within the same range.

The current report assesses the potential for exposure to boric acid in mattresses after 10 years of simulated use, using a number of conservative assumptions. These exposure estimates are compared against regulatory guidance provided by the U.S. EPA, U.S. CPSC and the National Academy of Sciences Food and Nutrition Board.

## ***Methods***

In July 2004, I met with Mr. Stephen Wolf, Vice President, Jones Fiber Products, Inc. to review the unique process used by Jones Fiber Products, Inc. for treating cotton batting with boric acid. As part of my evaluation, I reviewed this proprietary process, and I watched a videotape of the company's cotton batting manufacturing and treatment process.

In May 2005, I was contacted by Mr. Kenny Oliver, President, Jones Fiber Products, and I was asked to assist in the experimental design, conduct and evaluation of the current study. The ASTM hexagonal roller test was conducted by Stork Twin Cities Testing Corporation ("Twin Cities") in St. Paul, MN. Twin Cities has considerable experience in conducting ASTM hexagonal roller test. This test subjects the mattress to 100,000 strokes with a 240-pound roller, simulating 10 years of use.

Three mattresses were tested: two borate-treated cotton batting (Beds #1 and 2) and one mattress without borate-treated cotton batting (Bed #3). The two test beds were built by a regional customer of Jones Fiber in the exact same manner they build their TB 603 compliant beds that are being sold primarily in contract sales. There was a sacrificial layer of polyester over the barrier of boric acid-treated cotton at 1 ounce per sq/ft in the panel (top layer) of the mattress. In addition, there was boric acid-treated cotton blended with modacrylic in the border at 1 ounce per sq/ft with no sacrificial layer between the barrier and ticking. There were also boric acid-treated pads at 1.5 ounce per sq/ft inside directly over the spring unit (deep inside). In summary, the mattresses were built to directly correlate with what a consumer could expect to get. The untreated bed was built in the same manner but foam or Polyester was used instead of the boric acid cotton.

To evaluate the potential for exposure to boric acid, Twin Cities performed a wipe test on the bare top surface of each mattress. A total of six 5 x 5 inch areas (about 161.3 square centimeters each) were wiped tested on each mattress at each interval. Each

of the three mattresses was wipe-tested on four occasions for boric acid levels on the surface of the mattress. Each mattress was wipe tested after 0, 5000, 50,000 and 100,000 strokes of the roller. The purpose of multiple testing intervals was to assess the progressive impact of simulated wear on the surface concentration of boric acid. At each testing interval, six wipe tests were conducted on each mattress. The bed was divided into thirds: the top third, the middle third, and the bottom third. Wipe samples were taken on the right and left side of each of the mattress thirds, for a total of six wipe samples. The roller moved from side-to-side across the middle third of the mattress. The two wipe samples taken in the middle third of the mattress were composited to represent a sample inside the region of the mattress which the roller traversed. The remaining four wipe samples (in the top and bottom thirds of the mattress) were composited as a representative sample of the mattress surface outside the area where the roller traversed. It was hypothesized that the boric acid concentration would be greater within the roller area compared to outside the roller area.

Twin Cities performed a wipe test on the bare top surface of each mattress. A total of six 5 x 5 inch areas (about 10 x 10 cm) were wiped tested on each mattress at each interval.

The wipe testing was performed according to NIOSH method 9100 "Lead in Surface Wipe Samples" for surface wipe sampling patterns. The synthetic wipes were 9 x 9 inch TexWipes. They were moistened with pretested deionized water and folded into quarters. A clean laminated grid card with a 5 x 5 inch square (about 12.7 x 12.7 cm, or 161.3 cm<sup>2</sup>) hole in the center was placed over the mattress area with pressure applied. In a continuous S-shaped motion, the designated area was sampled three times; first, from left to right, top to bottom; second, from right bottom to top left; and third, from left bottom to right top. The wipe was then re-folded, exposing a clean surface, and the second of the five locations was sampled as outlined above. A total of five sections in an hourglass formation were sampled using one wipe folded in quarters. Powder-free, metals-free gloves were worn and changed between mattress samples. Thus, the combined surface area tested on each mattress was 322.6 and 645.2 cm<sup>2</sup> for "inside" and "outside" composites, respectively.

The analytical testing for boric acid was performed by West Coast Analytical Services (WCAS), an independent testing laboratory located in Santa Fe Springs, California. Boron was analyzed using inductively-coupled mass spectrometry. The results were reported as: (1) total micrograms (mcg) of boron (B) and (2) mcg of B per square centimeter (cm<sup>2</sup>) of the surface area of the TexWipe. For this risk assessment, it was necessary to calculate the mcg of B per cm<sup>2</sup> of mattress surface area. This was done by dividing the total mcg of B in the sample reported by WCAS by the surface area of the mattress sampled (either 322.6 or 645.2 cm<sup>2</sup>). A small amount of boric acid was expected on the surface of all mattresses (whether treated with boric acid or not) since it is a ubiquitous natural substance in air, water and soil.

There is no standard risk assessment methodology for assessing flame retardant chemicals in mattresses specifically. Although, in 2000, the National Academy of Sciences (NAS) published a report entitled "Toxicological Risks of Selected Flame-Retardant Chemicals." One of the substances reviewed by the NAS was zinc borate.

The present risk assessment was conducted using a series of conservative assumptions. These conservative assumptions would likely overestimate the risk, if any.

## ***Results***

### **Results of Wipe Tests**

The results of the wipe tests (Table 1) revealed an extremely low concentration of boron on the mattress surface, even for the mattresses that were not treated with boric acid. The concentration of boron on the mattress surface was about one order of magnitude higher for mattresses with borate-treated cotton batting ("borate-treated mattresses") than for untreated mattresses.

Insider the roller area, the two borate-treated mattresses demonstrated an average surface concentration of 0.337 micrograms boron per square centimeter at the end of the roller test (after 100,000 cycles). (A microgram is 1/millionth of a gram; a gram is 1/28 of an ounce.) In comparison, the surface concentration of boron outside the roller area (0.229 micrograms per square centimeter) was slightly less after 100,000 cycles. The single highest concentration on either mattress at any interval was 0.592 micrograms boron per square centimeter.

The wipe test results tended to rise during the course of the roller test. Average wipe test results inside the roller area for the treated mattresses increased by a factor of 2.1, 3.5, and 3.5 when tested at 5000, 50,000 and 100,000 cycles, respectively, compared to pre-test results. Similarly, outside the roller area, average wipe test results for the treated mattresses increased by a factor of 1.4, 2.0, and 2.5 when tested at 5000, 50,000 and 100,000 cycles, respectively, compared to pre-test results. Not surprisingly, the wipe tests results for the untreated bed did not change significantly during the course of the roller test.

**Table 1. Boron Levels on Mattress Surfaces (micrograms B/cm<sup>2</sup>) from Wipe Tests of Untreated and Treated Mattresses at Various Stages of Roller Testing (Artificial Aging)**

Bed	Pretest	5000 cycles	50,000 cycles	100,000 cycles
Untreated Control Bed	O: 0.014			
I:	0.015	O: 0.011		
I:	0.016	O: 0.010		
I:	0.013	O: 0.016		
I:	0.017			
Treated Bed #1				
	O: 0.074			
I:	0.080	O: 0.074		
I:	0.076	O: 0.117		
I:	0.119	O: 0.128		
I:	0.083			
Treated Bed #2				
	O: 0.104			
I:	0.112	O: 0.170		
I:	0.319	O: 0.245		
I:	0.561	O: 0.330		
I:	0.592			
<b>Average Treated</b>		<b>O: 0.089</b>		
<b>I: 0.096</b>		<b>O: 0.122</b>		
<b>I: 0.198</b>		<b>O: 0.181</b>		
<b>I: 0.340</b>		<b>O: 0.229</b>		
<b>I: 0.337</b>				

O = outside roller area (composite of 4 samples)

I = inside roller area (composite of 2 samples)

Control TexWipe values (3) were about half those observed for the untreated control bed; these control wipes are wipes which were not used on either treated or untreated mattresses.

## Risk Assessment

This risk assessment considered ingestion, dermal absorption and inhalation as possible pathways of exposure to boric acid for a consumer sleeping on a mattress.

### Estimate of Oral Exposure

Ingestion of boric acid from sleeping on borate-treated mattress is expected to be insignificant. The results of the wipe tests showed a very low concentration of boron on the bare mattress surface; the highest average and the highest single values in the wipe testing are 0.340 and 0.592 micrograms of boron per square centimeter, respectively (Table 1). In practice, consumers generally do not sleep on a bare mattress. Consumers typically use sheets and/or mattress pads which would serve as a barrier to prevent any ingestion of the small amount of boron on the mattress surface. However, for purposes of this risk assessment, a conservative assumption was made that a consumer sleeps on a bare mattress without a mattress pad or sheets.

In general, children would have limited oral contact with the surface of the mattress while sleeping on a mattress. However, it is possible that a child could "mouth" or lick a small area of the mattress surface. It is unlikely that the affected surface area would be more than about a square inch. However, for purposes of this risk assessment and for the sake of conservatism, it is assumed that a child licks an entire six-inch square area of the bare surface of the mattress per day, a highly unlikely scenario. If it is assumed that a child licks clean a 6 inch x 6 inch square area of a bare mattress surface, the amount of exposure would be about 78 micrograms of boron (231 cm<sup>2</sup> x 0.34 micrograms B/cm<sup>2</sup>) per day, assuming the concentration is the average wipe test result inside the roller area after 10 years of simulated mattress use (Table 2). This amount of exposure does not pose a significant risk, as will be demonstrated later in this report.

**Table 2. Highly Conservative Estimates of Daily Exposure to Boron (micrograms B per day) from Borate-Treated Mattresses after 10 Years of Simulated Use Based on Average and Highest Testing Results**

Route of Exposure Exposure (mcg B/day) based on average testing result<sup>a</sup>  
 Exposure (mcg B/day) based on highest testing result<sup>b</sup>

	Adult	Child	Adult	Child
Oral	2.2	78	3.8	137
Dermal	5.2	1.6	9.1	2.7
Inhalation	ND	ND	ND	ND
TOTAL	7.4	79.6	12.9	139.7

ND = not determined

<sup>a</sup> Average surface concentration inside the roller area based on average of two borate-treated mattresses after 10 years of simulated use was 0.337 mcg B/cm<sup>2</sup>.

<sup>b</sup> Highest surface concentration inside the roller area in either borate-treated mattress after 10 years of simulated use was 0.592 mcg B/cm<sup>2</sup>.

A similar calculation may be performed assuming the mattress surface is the highest single value observed in the wipe test results (0.592 micrograms B/cm<sup>2</sup>). Accordingly, if it is assumed that a child licks clean a 6 inch x 6 inch square area of a bare mattress surface, the amount of exposure would be 137 micrograms boron (231 cm<sup>2</sup> x 0.592 micrograms B/cm<sup>2</sup>) per day, assuming the bare mattress surface has the maximum concentration found in the wipe tests (Table 2). Once again, this calculation assumes that there is no mattress cover or sheet on the mattress. This amount of exposure does not pose a significant risk, as will be demonstrated later in this report.

Adults would be expected to have even less oral exposure to boron while sleeping on a borate-treated mattress. For these calculations, it is assumed that the adult sleeps on a bare mattress containing the average surface concentration of boron found in the wipe tests. If it is conservatively assumed that an adult is less likely to lick the surface of a bare mattress, the oral intake of boron for an adult would be even less than the conservative estimate for a child, or about 2.2 micrograms boron per day (assumes an adult licks only 1 square inch) (Table 2). If the surface concentration of boron on the mattress is assumed to be the maximum value found in the wipe testing, the oral intake of boron would be about 3.8 micrograms boron per day (Table 2). This amount of exposure does not pose a significant risk, as will be demonstrated later in this report.

### Estimate of Dermal Exposure

Dermal exposure of boron from a mattress would be negligible since boric acid is poorly absorbed across the intact skin. Dermal exposure may be estimated by making a series of conservative assumptions. For example, for these calculations, it is assumed that an adult sleeps naked on a bare mattress and that the entire surface of the body is in constant contact with the mattress for 8 hours (an impossibility since a person can only sleep on one side of the body at a time). In reality, less than half the surface area of the body would be in contact with the mattress surface, even sleeping naked on a bare mattress. Both the surface area of an adult and the surface area of a twin bed are about 20,000 cm<sup>2</sup>.<sup>3</sup> Therefore, it is assumed that the body surface is in contact with the total amount of boron on the surface of a twin mattress.

In a carefully conducted study of dermal absorption of boric acid in humans, researchers at the University of California, San Francisco found that only 0.23% of a saturated solution of boric acid was absorbed following skin contact for 24 hours (Wester et al.). Adjusting for 8 hours, this yields a skin absorption rate of 0.077% per 8 hours of skin contact with a saturated solution of boric acid. It is conservatively assumed that the skin absorption of a low concentration of boric acid would be the same as that of a saturated solution. By making another conservative assumption of 100% transfer of boron from mattress to skin, the skin surface concentration is assumed to be 0.34 micrograms B/cm<sup>2</sup>, which was the average surface concentration on the borate-treated mattresses inside the roller area after 100,000 cycles. Therefore, a highly conservative estimate of the amount of dermal absorption of boron for an adult sleeping naked on a bare borate-treated mattress for 8 hours per day is 5.2 micrograms of boron per day (20,000 cm<sup>2</sup> x 0.34 micrograms B/cm<sup>2</sup> x 0.00077), which is an insignificant amount (Table 2). If it is assumed that the surface concentration is the maximum value found in the wipe testing, a highly conservative estimate of the amount of dermal absorption of boron for an adult sleeping naked on a bare borate-treated mattress for 8 hours per day is 9.1 micrograms of boron per day (20,000 cm<sup>2</sup> x 0.592 micrograms B/cm<sup>2</sup> x 0.00077), as shown in Table 2. This amount of exposure does not pose a significant risk, as will be demonstrated later in this report.

Estimates of dermal absorption for children would be proportionately less, based on body surface area. For example, a 2-3 year old child would have an average body surface area of about 6,000 cm<sup>2</sup>.<sup>4</sup> Therefore, a conservative estimate of dermal absorption of boron for a 2-3 year old child would be 30% (6,000/20,000) of the adult value, or 1.6 or 2.7 micrograms boron per day assuming the average and maximum concentration, respectively, from the wipe testing (Table 2). This amount of exposure does not pose a significant risk, as will be demonstrated later in this report.

## Estimate of Inhalation Exposure

Inhalation exposure to boron is expected to be insignificant. Boric acid is not a volatile substance, and it would not be present as a vapor. Normal sleeping activity would not be expected to create a significant air concentration of boron. It may be hypothesized that during sleeping, the mouth or nostrils are placed directly against the surface mattress and a small amount of boron might be inhaled. However, this risk assessment already assumes that all of the boron on the mattress surface area near the mouth and in the breathing zone is ingested. In essence this risk assessment has already accounted for the small insignificant amount, if any, of boron that might be inhaled.

Another possible scenario is a young child jumping on a bed. An overly conservative estimate of exposure may be derived making a number of conservative, if not impossible, assumptions. The following assumptions are made: (1) the mattress is bare (no sheet or mattress cover), (2) the respiratory rate for a young child jumping on a bed is  $5 \text{ m}^3$  of air per 8 hours, half that of an adult worker ( $10 \text{ m}^3$  per 8 hour workday), (3) a child jumps on the bed continuously for 15 minutes per day every day, and (4) 10% of the boron on the surface of a twin mattress ( $0.34 \text{ mcg/cm}^2 \times 18,631 \text{ cm}^2 \times 0.1 = 633 \text{ mcg B}$ ) is evenly suspended in the air one meter above the surface of the bed (a volume of air of about  $2 \text{ m}^3$  for a twin mattress) continuously for 15 minutes, and (5) the air in the meter above the bed does not mix with any of the other air in the room, and (6) when jumping on the bed, the child inhales only the air one meter above the mattress surface.

Making these conservative assumptions, the air concentration above the mattress would be  $317 \text{ mcg B/m}^3$  ( $633 \text{ mcg B} \div 2 \text{ m}^3$  of air), and an overly conservative estimate of the amount of boron a child would inhale from jumping on the bed is about 50 micrograms of boron. In reality, a more reasonable, but still conservative, estimate of the amount of boron inhaled from jumping on a bed is probably an order of magnitude below this estimate, or about 5 micrograms boron per day. Estimates of inhalation exposure were not included in Table 2 because of the higher degree of uncertainty compared to the oral and dermal estimates. However, even for a child jumping on a bed for 15 minutes everyday, inhalation appears to be a less important route of exposure compared to the conservative estimates of ingestion.

## Regulatory Guidelines and Standards

The Consumer Protection Agency has established an Acceptable Daily Intake (ADI) for boric acid of  $0.088 \text{ mg B/kg/day}$  (Table 3). The ADI is based on a No Observed Adverse Effect Level (NOAEL) in dogs and a 100-fold uncertainty factor. This is a dose that should pose no significant risk to humans. For a 70 kg person, the ADI is 6,200 micrograms boron per day. For a 10 kg child, the ADI is 886 micrograms boron per day.

In 2004, the U.S. Environmental Protection Agency (EPA) issued its current Reference Dose of  $0.2 \text{ mg B/kg/day}$  (Table 3). EPA defines its Reference Dose as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. For a 70 kg person, the Reference Dose is 14,000 micrograms boron per day. For a 10 kg child, the Reference Dose is 2,000 micrograms boron per day.

The National Academy of Sciences Food and Nutrition Board established an Upper Limit (UL) for daily exposure to boron (Table 3). The UL is established according to age group. For an adult, the UL is 20,000 micrograms boron per day. For a 1-3 year old child, the UL is 3,000 micrograms boron per day.

When the conservative estimates of exposure to boron from borate-treated mattresses are compared to these regulatory guidelines, it is clear that exposures are well below the safety guidelines established by the CPSC, US EPA and the National Academy of Sciences' Food and Nutrition Board (Table 3). In fact, the conservative estimates of exposure to boron for a child sleeping on a bare borate-treated mattress after 10 years of simulated use are 6-45 times below the regulatory ADI established by the CPSC. For an adult, the estimated exposure is about 480-3445 times below the CPSC ADI. It is important to recognize that the ADI already includes a 100-fold uncertainty factor to protect humans.

**Table 3. Comparison of Conservative Exposure Estimates to Regulatory Guidelines**

Source or Regulatory Standard	Adult (mcg B/day)	Child (mcg B/day)
Borate-Treated Mattress – after 10 years simulated use (conservative estimate based on average test results)	7.4	79.6
Borate-Treated Mattress – after 10 years simulated use (conservative estimate based on lowest and highest test results)	1.8-12.9	19.6-139.7
Consumer Product Safety Commission Acceptable Daily Intake (0.088 mg B/kg/day) <sup>5</sup>	6,200 <sup>a</sup>	886 <sup>b</sup>
US Environmental Protection Agency Reference Dose <sup>6</sup> (0.2 mg B/kg/day)	14,000 <sup>a</sup>	2,000 <sup>b</sup>
National Academy of Sciences Food and Nutrition Board Upper Limit (1-3 yr olds)	20,000	3,000

<sup>a</sup> Assuming adult body weight of 70 kg (154 pounds)  
<sup>b</sup> Assuming child body weight of 10 kg (22 pounds)

Compared to the UL established by the National Academy of Sciences Food and Nutrition Board, conservative estimates of exposure to boron (based on the range of test values) from sleeping on a bare borate-treated mattress are 21-153 and 1550-11,100 times below the UL for children (1-3 years old) and adults, respectively.

**Daily Exposure to Boron from Various Sources**

It is useful to compare the conservative estimates of exposure to boron from borate-treated mattresses to other daily exposure to boron from various sources. Table 4 summarizes a number of daily exposures to boron from various sources, including many common food, as well as total dietary intake. For an adult, these comparisons show that a conservative estimate of exposure to boron from sleeping on a borate-treated mattress is

**Table 4. Daily Exposure to Boron (B) from Various Sources**

Source	Exposure (mcg B/day)
Bare borate-treated mattresses (10 years of simulated use), <b>adult</b> (range of conservative estimates based on single highest and lowest wipe test values)	1.8-12.9
Bare borate-treated mattresses (10 years of simulated use), <b>child</b> (range of conservative estimates based on single highest and lowest wipe test values)	19.6-139.7
Centrum vitamin tablet	50
Milk (toddler)	100 <sup>a</sup>
Juice (toddler)	119 <sup>a</sup>
Fruit (toddler)	86 <sup>a</sup>
Grape juice (6 ounces)	622 <sup>b</sup>
Peanut butter ( 1 ounce)	406 <sup>b</sup>
Peanuts, dry (1 ounce)	386 <sup>b</sup>
Avocado (1 ounce)	311 <sup>b</sup>
Total dietary intake (toddler)	670 <sup>c</sup>
Total dietary intake (4-8 year olds)	800 <sup>d</sup>
Total dietary intake (9-13 year olds)	860 <sup>d</sup>
Total dietary intake (14-18 year olds)	840 <sup>d</sup>
Adult dietary intake (average)	1200 <sup>d</sup>
Adult male dietary intake (95 <sup>th</sup> percentile)	2300 <sup>e</sup>
Adult female dietary intake (95 <sup>th</sup> percentile)	1800 <sup>e</sup>
Vegetarian male dietary intake (95 <sup>th</sup> percentile)	2700 <sup>e</sup>
Vegetarian female dietary intake(95 <sup>th</sup> percentile)	4200 <sup>e</sup>

<sup>a</sup> Meacham SL and Hunt CD (1998)

<sup>b</sup> Anderson et al. (1994)

<sup>c</sup> Rainey et al. (1996)

<sup>d</sup> Rainey and Nyquist (1998)

<sup>e</sup> Rainey et al. (1999)

about three orders of magnitude less than typical dietary intake. A single serving of foods rich in boron provide much greater exposure to boron than could ever be encountered by sleeping on a borate-treated mattress. For example, a single 6-ounce serving of grape juice contains 622 micrograms of boron, which is about 48-345 times the conservatively estimated exposure to boron from sleeping on a bare borate-treated mattress.

Toddlers will receive about 5-34 times more boron in their diet than the conservatively estimated exposure to boron from sleeping on a borate-treated mattress. In fact, for a toddler, average daily consumption of milk alone provides more exposure to boron than a conservative estimate of the average exposure from sleeping on a borate-treated mattress. The same is true for a toddler’s daily intake of juice and fruit.

## Conclusions

The boric acid-treated cotton batting in borate-treated mattresses is designed to be lasting and is not fugitive.

The wipe tests confirm that the boric acid in borate-treated mattresses is not fugitive, since very little boron was found on the mattress surface, even after 10 years of simulated use.

Conservative estimates of exposure to boron from sleeping on borate-treated mattresses, based on wipe test results after a roller test simulating 10 years of use, show negligible exposure for both adults and children. The estimates were based on a series of conservative assumptions, which are designed to err in the direction of overestimating exposure. For example, it was assumed that a person sleeps naked on a bare mattress with 100% of the body surface in contact with the mattress surface. Similarly, it was assumed that a child licks a 6 x 6 inch area of the surface of a bare mattress daily.

Even after 10 years of simulated mattress use, all exposure estimates for borate-treated mattresses are far below regulatory guidelines and standards for boron established by the Consumer Product Safety Commission, the U.S. Environmental Protection Agency, and the National Academy of Sciences Food and Nutrition Board.

A limitation of this study is the small number of borate-treated mattresses that were wipe tested. However, the wipe test results in this study are consistent with the earlier testing of three borate-treated mattresses, which were sampled in a retail showroom (without a roller test). In the earlier study, the average surface concentration was 0.110 micrograms of boron per square centimeter, compared to an average of 0.089-0.096 in the present study for wipe samples taken prior to the start of the roller test. Similarly, the maximum surface concentration was 0.197 micrograms of boron per square centimeter in the earlier study (no roller test), compared to 0.592 micrograms of boron per square centimeter in the present study for the highest wipe test result inside the roller area after 10 years of simulated use. It is likely that the mattresses in the showroom were subjected to some degree of usage by customers "testing" the mattresses, but not to the same degree as the mattresses in the present study subjected to 100,000 roller cycles to simulate 10 years of use.

Another possible limitation of this study is that natural aging of a mattress may differ from the artificial aging provided by the ASTM hexagonal roller test. However, the differences are expected to be small, since the ASTM hexagonal roller test is widely used to test the quality and longevity of mattresses. There is no reason to suspect that more boron would be released by natural aging and usage than by artificial aging and usage. In fact, under the ASTM hexagonal roller test conditions, any boron was allowed to accumulate on the bare mattress surface without removal.

The results of the present study showed that the "untreated" mattress had smaller, but measurable, quantities of boron on the mattress surface. At the start of the study, the concentration of boron on the mattress surface was about six times higher for mattresses with borate-treated cotton batting ("borate-treated mattresses") than for untreated mattresses. A similar result was obtained in a previous study of treated and untreated mattresses on the showroom floor.

The present study was not designed to directly address the issue of potential inhalation exposure resulting from children jumping on a mattress. It is my understanding that additional testing, sponsored by the National Cotton Batting Institute (NCBI) is under way to assess this issue.

And finally, at the end of this study, the borate-treated mattresses were tested by Twin Cities to confirm that the mattresses retained their flame resistant properties after 10 years of simulated use. It is also my understanding that the borate-treated mattresses used in this study passed the TB-603 flame resistance test. These test results provide additional evidence that little borate is lost after 10 years of simulated mattress use.

In summary, the use of borate-treated cotton batting in mattresses poses no significant risk to human health. In fact, a person is expected receive more exposure to boric acid by eating fruits and vegetables than by sleeping on a treated mattress.

<sup>1</sup> Murray, FJ (2005) Risk Assessment of Boric Acid in Serta FireBlocker Mattresses. February 7, 2005.

<sup>2</sup> In this report, the term "boron" or "B" is used in a generic sense and only refers to the boron content of boric acid and borates, since elemental boron does not exist in a free state in nature. For purposes of comparison, the amount of boric acid may be converted to boron (B) equivalents based on the fraction of boron on a molecular weight basis as follows: amount of boric acid x 0.175 = equivalent amount of boron. To convert from boron (B) to boric acid multiply by 5.72.

<sup>3</sup> Reference for surface area of adult human body is: <http://www.epa.gov/ncea/pdfs/efh/sect6.pdf>. Area of the top surface of a twin mattress is 18,631 cm<sup>2</sup> (based on 39 x 74 inches).

<sup>4</sup> <http://www.epa.gov/ncea/pdfs/efh/sect6.pdf>

<sup>5</sup> <http://www.cpsc.gov/library/foia/foia05/brief/mattressespt3.pdf>

<sup>6</sup> EPA defines its Reference Dose as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."