Sleeping on Toxins? A Study of Flame Retardants in Sleep Products

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ABSTRACT

Fires and fire damage result in thousands of lives lost or injured each year. The need to protect our homes and furniture from accidental fires has resulted in flammability laws that require the addition of flame retardants into everyday products. However, the very properties of the chemicals that make them so effective also make them toxic. Recently, studies show that these flame retardants have carcinogenic properties and result reproductive and neurological toxicity as well as. Studies have evaluated furniture foam and the foam of baby products but no investigations have focused on foam mattress pads and nursery school sleeping mats for their chemical content. I studied foam samples of over 50 mattress pads and 30 nursery school using particle induced X-ray emissions and gas chromatography/mass spectroscopy provided by Hope College. All of the nursery school sleeping mats and 50% of mattress pads tested positive for halogens regardless of the year of purchase and the lack of a flammability standards; but there were no significant trends by the store of purchase. An interview was also conducted with a federal official from the Consumer Product Safety Commission to better understand the reasoning for the addition of toxic flame retardants. The presence of chemicals in the products shows disconnect between the flammability standards, manufacturer practices and consumer knowledge and choice on flame-retardants. The flammability standards need to be re-evaluated and flame-retardants need further research before they are deemed safe.

KEYWORDS

Polyurethane foam, TB 117, Mattress Pads, Flammability standards, Chlorinated Tris

INTRODUCTION

Fires and fire damage result in thousands of injuries and lost lives and cost over 14 billion dollars in losses in 2008 (Karter et al. 2008). The need to protect homes and from fire has resulted in flammability standards. Flame retardants serve to slow the combustion of treated materials and, flame retardants are often added into plastics, foam, fabric etc. in order to meet state and federal flammability standards (Alaee M. et al 2003, Dishaw et al 2011). Currently, the largest share of the market for flame retardants belongs to brominated flame retardants (Birnbaum et al 2004). These flame retardants are added to our furniture to meet one flammability regulations implemented in 1975 called California Technical Bulletin 117 (TB117) to The goal is to reduce the number and intensity of house fires and fire related damages and deaths (Guerra P. et al. 2011). To meet this regulation, foam and furniture companies use chemical additives, particularly halogenated compounds as they are the most cost efficient and effective (Rahman F. et al. 2001). Halogenated flame retardants are effective due to their ability to interfere with the combustion process by removing gaseous radicals which disrupts the combustion chain reaction and reducing the propagation of the flame (Alaee M. et al 2003**,** Rahman F. et al. 2001). Flame retardants only get incorporated into the physical matrix and are not chemically bound to the foam. As such, the compounds can easily escape into vapor form when there is enough heat and can absorb the energy of the fire (Renner R. 2000).

Unfortunately, the halogens which make the flame retardants effective, are also the cause of their toxicity as the chemicals leach from foam products in normal atmospheric conditions (Hale et al 2001). The halogen to carbon bonds are not natural structures. The carbon structures that the halogens attach to are also non-polar and the flame retardant compounds, especially Polybrominated Diphenyl Ether (PBDE) have high affinity to fat, lipophilicity, and are highly resistant to degradation which can result in bio accumulation (Rahman et al 2001). High lipophilicity of a compound results in the compound migrating to fat storage areas such as breast tissue and fat deposits which allows the compound to persist in the body. The most studied flame retardants; Polybrominated Diphenyl Ethers (PBDEs) has been found in all tropic levels of the biota from sewage sludge, to the breast milk of mothers (Birnbaum et al. 2004). Studies also compare the unusually high level of PBDEs, in the blood of populations around the world with the populations in North America, particularly California, which has the highest concentration due to the nation's strict flammability regulations (Zota et al. 2008, Trudel et al 2011). New flame retardants such as Firemaster 550, which is a replacement for PBDEs, has already been found in Belgium, and mixtures of new flame retardants are appearing in US household dust (Ali et al. 2011, Stapleton et al. 2008). Because the compounds have been found in adipose, blood and breast milk of humans the presence of flame retardant compounds in the dust raises concern about long term toxic effects (De Wit C. 2002).

The high exposure from dust is concerning because the flame retardants have been found to have dangerous long term health effects. PBDEs have been suggested to have negative neurological, reproductive, and developmental properties. (Hallgren et al. 2001, Eriksson et al. 2001, Birnbaum 2004). Recent research has also suggested the possibility of carcinogenicity. (NTP) Many of the newer flame retardant chemicals however, have not been extensively studied so true effects of their long term exposures are unknown. One of the newer halogenated flame retardant, Firemaster 550, has a slower photodegradation rate than PBDEs which suggests it will persist in the environment for longer periods of time (Davis et al 2009). It has also been shown to bioaccumulate and induces DNA damage (Bearr et al. 2010). Chlorinated TRIS, a compound that was banned from children's pajamas but now is a halogenated additive to flame retardants, have been hinted to have not only carcinogenic properties, but also more severe neurologic toxic effects than PBDEs and reproductive toxicities (Blum et al 1977, Dishaw et al. 2011, Meeker et al. 2009). Despite all the evidence to suggest toxicity of the chemicals, the flame retardants continue to be ubiquitous in our environment due to several standards and regulations.

Several flammability standards exist which necessitate the addition of halogenated flame retardants to consumer products, all of which prove to be outdated and lack fire safety benefits. Regardless of the lack of regulation however, halogenated flame retardants have been found in many different consumer products. Currently there is no law requiring the addition of flame retardants to egg crate foam mattress pads without any coverings. Table 1 illustrates the main flammability regulations and the products they regulate.

Table 1. Flammability Regulations and Requirements. (Consumer Product Safety Commission and State of California.)

Flammability Regulation	Consumer Products Regulated	Requirement
TB 117	Filling material of upholstered furniture	Must be able to withstand a 12 second small open flame without combusting
16 CFR 1632	Mattresses and Covered Mattress Pads	Must be able to withstand the burning of a full cigarette on any of its 6 surfaces with no more than a 2 in char mark around the cigarette
16 CFR 1633	Mattresses, Box Springs and Futons etc (excluding mattress pads)	When subject to an open flame the mattress sets must not exceed a 200 kilowatts (kW) peak heat release rate within the 30 min of the test

Furthermore, the flammability standards have a lack of fire safety benefit. In a realistic setting where the fire is uncontrolled, the presence of the organohalogen flame retardants, results in more dangerous compounds such as brominated or chlorinated furans. Adding halogenated flame retardants also results in an increase production of carbon monoxide when burned (Schnipper A et al. 1995). Also, the burning of flame retardant containing products results in not only increased production of carbon monoxide but also of powerful irritant acidic gases such as HCl and respiratory irritants such as partially burned hydrocarbons (Shaw et al. 2010). This raises an issue because a large percentage of the fire related deaths can be attributed to inhalation of toxic combustion products such as carbon dioxide. Lung irritants have also been suggested to play a role in the delayed death of fire victims (Birky M et al. 1981). Unfortunately there is no data regarding the flame retardant content of many unregulated products which is concerning considering that the fire safety benefit of the compounds have come under fire.

Studies have evaluated furniture foam and the foam of baby products but no one has looked at foam mattress pads, nursery school sleeping mats and their chemical content (Stapleton et al. 2009, Stapleton et al. 2011). Although no legislation requires the addition of flame retardants to mattress pads, the possible presence of these toxins is concerning because we spend an average of 7 hours on our beds resulting in a high exposure. Sleeping mats are also commonly used in nursery schools and the presence of flame retardants in these pads would result in constant long term exposure of vulnerable children to these chronic toxins.

My study will examine the flame retardant content of mattress pads and other similar foam sleep products' flame retardant content. In addition I will explore the different factors such as location, time and place of use in predicting the presence of flame retardants in order to shed light on factors that could influence their addition. My first objective is to determine if location of use, home vs. daycare, is correlated with flame retardants used. My second objective is to explore if the flammability standard tags influence the type of flame retardants added. My third objective is to look to see if different locations of purchase results in different flame retardants found. I also wanted to see if there are any time trends regarding flame retardant addition to the products. Even though there is no requirement for their addition in mattress pads and sleeping mats, I believe that these chemicals are still used and I want to explore the reasoning behind the addition of these toxic chemicals in consumer products.

METHODS

Sample Collection: Nursery School Sleep Products

In order to collect samples of sleep products from nursery schools for my study, I reached out to umbrella organizations of nursery schools and day care centers around the Bay Area to solicit their help. Each organization was sent a short description of the study to distribute to their nursery schools and daycare centers and I accepted all interested schools into our study.

We first we surveyed the foam sleeping products in a facility to determine the number and types of products (e.g. sleeping mats, mattress pads, foam mattresses, mattresses) that the children use. I noted the number of different brands and type of foam products, and documented the type of flammability standard labels. I tried to take a representative sample of the sleep products, with at least two samples for each brand/type when possible. I sampled the mats which had easier access to the foam. I wore gloves and used scissors to collect ¼ cubic inch of foam. I placed my samples in aluminum foil to avoid any contamination leaching of the chemicals before double bagging them in Ziploc bags. I also developed a new foam collection survey to be used and for both the nursery school and sleeping mat collection. I recorded the type of flammability label, if present, as well as the manufacturer, brand, and year purchased using the survey I developed. I also collected usage data on the sleeping product through the survey that was filled out with every sample. I managed to collect 20 samples of at least 4 different types of sleeping mats. However the background data was only complete for three of the types found and flammability labels only present for two of the types. Many of the products actually did not have any type of flammability label.

Sample Collection: Mattress pads

I sent out a request for samples among friends, UC Berkeley list-serves and among other interns working with my mentor, to obtain a diverse sample of mattress pads from different stores. I also created a new foam collection survey, which is used for both the nursery school sleeping mat and mattress pad sample collection. I assembled sample kits with the aluminum foil and survey and placed the double bagged sample kits in a building on campus for pick up and drop off for the list serves.

Lab Analysis: PIXE and GC Mass Spec.

Each sample was separated from the foam collection survey and the survey data were coded into a database with the sample ID in order to strip the data of its identifiers. The samples were then sent to at the Peaslee lab of Hope College in Holland, Michigan.

The laboratory analysis of my study was undertaken at Hope College by Graham F. Peaslee's lab in the department of Chemistry and Environmental Science The Peaslee lab used Particle Induced X-ray Emission to detect the presence of halogens in the polyurethane foam samples. Polyurethane foam normally only consists of nitrogen, hydrogen, carbon and oxygen (Seymour R. et al. 1992). Halogens are only present with the addition of chemical flame retardants. PIXE has been used before in studies of air pollution and marine aerosols to detect elements and this method is relatively accurate in its detection of halogens (Maenhaut et al. 1987). The lab also ran Gas Chromatography Mass Spectroscopy (GS/MS) on select samples that came back positive to further elaborate on the type of flame retardants that were used in the products. After the samples were analyzed, the results were sent back to Berkeley.

Interview

I also conducted an interview with an official from the Consumer Product Safety Commission to determine the possible influencers in the decision making processes of adding certain flame retardants to products. Her identity has been kept confidential. I asked clarification questions regarding the flammability laws and if either bare foam mattress pads or nursery school sleeping mats fall under any flammability regulations. I also asked her opinion on the level of knowledge that she believes manufacturers might have on the flammability standards, how the standards are often met, does she think manufacturers add flame retardants, if the standards are strictly regulated and if she thinks the policies could be changed in the future.

Data analysis

Once the PIXE analytic data was available, I reviewed the data set to determine if there were any relationships between flame retardant addition to products and my factors of interest. In order to do this, I ran a logit generalized linear model to analyze if there were any relationships between stores of purchase and presence of chemicals. I set up four separate data sheets: chlorine, bromine, both and neither. For each I coded every sample in with a 1 in the column corresponding to the place of purchase, or in the DK (don't know) column if unknown and 0 for the other stores. Using R, I inputted two outcome variables, presence or absence of the halogen of interest, and the predictor variables, the different stores. I also specified the different store outputs to be factors. My formulas are available in Appendix A. I ran the test 4 times for each of the four separate data sheets.

In addition, I ran a chi squared text to test for a difference between the presence and absence of flammability labels. I also collected time data to determine if there is a time trend of flame retardants used.

RESULTS

Nursery School Sleeping Mats

I sampled 4 different nursery schools and obtained 22 samples of sleeping mats. Out of the 22 samples, I found that all samples came back positive for chlorine and four of them also had positive readings bromine. GC/MS was performed on 12 of the samples and the chemicals were identified to be Chlorinated Tris and TCPP, a similar compound. The schools all bought their mats after 2002 and most of them could not specify the year due to constant repurchasing and removal of mats from circulation. Most of the mats (18 out of 22) also did not have any flammability labels. However, four mats did have labels which cited TB 117. Currently, the mats purchased came from only two known manufacturers so I was unable to determine if there was relationship between manufacturers and the presence of flame-retardants.

Mattress pads

I had 56 total samples for mattress pads, 53 of which has been analyzed and 31 (55.4%) of the analyzed samples came back positive for halogens. Of the samples analyzed, 31 have basic data on location of purchase and three have GC/MS data in addition to the PIXE scan results. 28 samples had data on results and dates. The dates of purchase for the samples ranged from 1988-2011. Out of the 28 samples with time data, 12 (42.9%) had a negative PIXE result for both halogens. There were not enough data points to graph a time trend.

The logit test explores the relationship between different locations of purchase and the presence or absence of flame retardants. Only one of the analysis came back significant: Target and the presence of Chlorine in the mattress pads (p=0.0095). The breakdown of the chemicals found by store can be seen in Figure 1.

Most of the pads did not have any flammability labels. Out of the 56 samples analyzed, 31 (came back positive with no labels. One of the samples cited an unknown label, 16 came back negative with no labels and 4 came back negative with a label and 3 had no data. The presence of labels had a significant relationship with the absence of chemicals (p-value= 0.00949).

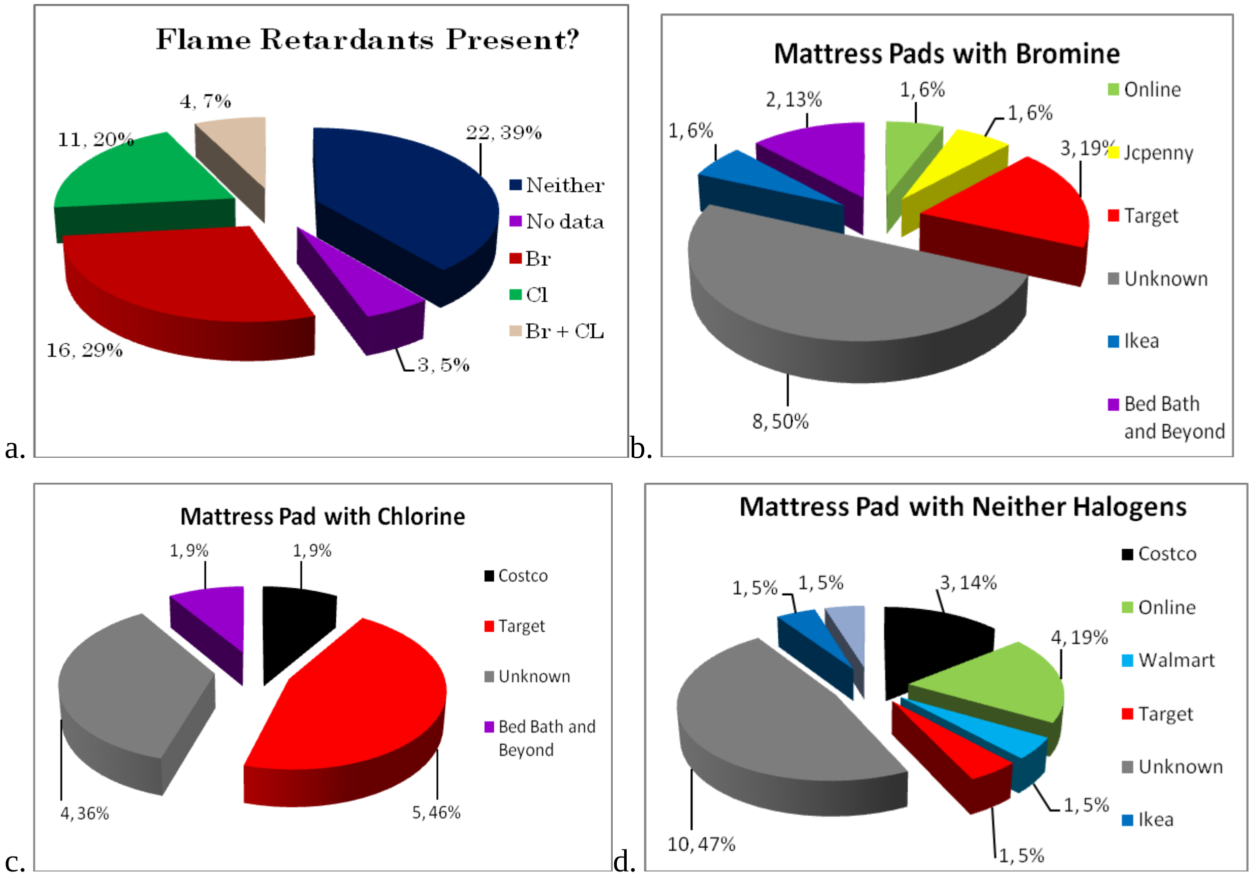

Figure 1. Breakdown of chemicals found in mattress pads A) Overall breakdown of chemicals found in mattress pads. B) Breakdown of mattress pads with Bromine by store. C) Breakdown of mattress pads with Chlorine by store D) Breakdown of mattress pads with neither chemicals by store.

Interview

I conducted a semi structured interview with an official from the Consumer Products Safety Commission to try to determine reasons for the addition of flame retardants and their current feelings on the law. I found that most of the federal standards do not require flame retardants; in fact they are met through barrier technology. Barrier technology is basically the use of non flammable materials around the foam itself so that it resists flames. Even though the commission tries to regulate the safety of products, they can only do so much with number of products on the market. I also found that there are some grey areas in the policy because the nursery school sleeping mats do not fall under the federal or state standard but yet they are cited under TB 117. The agency also does its best to inform manufacturers of the laws. Every time a law is changed a dialog is started between all the manufacturers and workshops and informational meetings are implemented to get feedback as well as inform them about the change.

DISCUSSION

Mattress pads and nursery school sleeping mats are used daily by students, children and adults. Although these mattresses do not fall under the flammability regulation TB 117, a stringent standard only found in California, many of these labels state that the mattresses meet the standard. In Zota et al. and in talks by Dr. Arlene Blum, they noticed that PBDE was used almost solely in the US and to comply with California's TB 117. Unfortunately the addition of PBDEs and other novel flame retardants only results in unnecessary exposure to toxic chemicals. The addition of chemical flame retardants is of great concern because these products do not need flame retardants and the flammability standard has been proven to have no fire safety benefit (Shaw et al 2010).

Nursery School Sleeping Mats

My finding that all of the nursery school sleeping mats are positive for flame retardants is of great concern because the most widely used flame retardants, PBDE, Firemaster 550 and Chlorinated TRIS, have recently been shown in recent studies to cause developmental, reproductive and carcinogenic effects (Blum et al 1977, Bearr et al. 2010, Crump et al 2012, Dishaw et al. 2011, Meeker et al. 2009). In my informal interview with an official from the Bureau of Home Furnishings and Thermal Insulations, nursery school nap mats only fall under the federal standard 16 CFR 1632, not TB 117, and that is only if they are larger than 2 feet by 3 feet. However, in my interview with the official from Consumer Products Safety Commission, nursery school sleeping mats were not concretely determined to fall under 16 CFR 1632. The official said that the agency must look at the product and judge because generally juvenile products do not have to follow the standard, and there is certainly not a size requirement for the standard (Gaw, Personal Communication CPSC). In my study, all of the sleeping mats studied are larger 2 by 3 feet. The few labels found on the mats regarding flammability regulations support my idea that manufacturers do not know which standard to use as they all cited TB 117, the stringent California furniture flammability standard. The labels found suggest that they are all using the same flame retardant treated foam as those put into furniture because TB 117 is a furniture standard which is so strong companies often use flame retardants to meet the standard. TB117's jurisdiction does not extend to nursery school sleeping mats. Manufacturers are meeting California's standard because it is the strictest of the whole nation in order to avoid liability and avoid keeping double inventory (Barbrauskas et. al. 2011). When I looked at the two main suppliers for sleeping mats in the Bay Area, I found that one of them advertises the fact that there are flame retardants. This finding illustrates that manufacturers believe flame retardants are good for the safety of the children when they are not.

Mattress pads

Even though there is no law that requires the addition of flame retardants to mattress pads, almost half of my mattress pads came back positive, and only one relationship between store and chemicals were found: Target and the presence of Chlorine. However, these results could be skewed due to the non-response bias in the survey. Also to successfully run a logit test, we would need about 120 samples so the small sample size could result in the not significant finding. The overall data suggests that the different manufacturers could be using different practices and chemicals when they make the mattress pads as there were no overall trends and only one significantly relevant relationship by store. The data could also be skewed as many people did not remember the store of purchase and turned in incomplete forms, resulting in non-response bias. Regardless, the finding that almost half of the mattress pads contain flame retardants is concerning because it shows that chemicals are being added into consumer products without any laws dictating its addition, resulting in unnecessary, long term exposure for a huge population.

The relationship between the presence of a TB 117 flammability label and the presence of flame retardant was also found to be statistically significant. In fact it would seem as if the tags result in a protective effect against flame retardants. However, the data for this is skewed as consumers usually discarded the packaging after purchase and my pilot study found that the flammability labels were mostly on the packaging. This relationship is opposite of one found by Dr. Arlene Blum's couch study which found that all samples received from California that had labels also came back positive for chemicals and 96% of those samples from outside California with labels also came back positive for chemicals (Blum et al, unpublished data). The lack of regulatory authority makes it difficult for CPSC to continually monitor the products as well as inform manufacturers of the differences in the laws. A furniture representative reported that the company often just meets whatever standards the store requests and many stores often try to avoid double inventory so they just choose to meet the strictest standards, which is California's TB 117 (Barbrauskas et al 2011, Gaw, Personal Communication). As such there are many gaps in knowledge in the industry and in the market place about the health effects of these chemicals and the requirements of the law. Also, the addition of the chemicals affects the integrity of the products (Gaw, Personal Communication). There are many alternatives to the current flame retardants but most manufacturers would rather save money than redesign their products to meet it without chemicals.

Limitations

One limitation of my study is that the number of schools participating in the nursery school portion of the study was lower than expected, which may be a result of a few different factors. First, the schools might not use these types of products. I received two responses from schools stating that they would not like to participate because they do not use these types of products in their schools. Second, another possible reason is that the schools are too busy. Third, they would not like to get involved in the study due to confidentiality and worry about the consequences on business if we do find toxic chemicals in the products they purchased.

A limitation for the mattress pad portion of the study was that there were many incomplete sample data points. Everyone did not fill out the survey in regards to when and where the mattress pad was bought which does end up changing the relationships found. To have more samples from different stores would be better in order to have a stronger correlation as well. The fact that most of the samples were collected from California also limits my inference because TB 117 is a California standard so the findings here might not be the same as findings in other parts of the nation.

There are also limitations for the statistical analysis. As mentioned in the discussion, the sample size for mattress pad by store is small which could explain the non-significant results. More data points by store need to be collected before any of the tests can be considered truly significant. A similar issue also arises for the Chi-Squared analysis of the flammability labels as many of the labels on the products examined are often removed before use which skews the data towards non-significance.

Further Research

Further research is needed to look at the overall trends of mattress pads and nursery school mats by state and manufacturer and flammability label in order to get a broader understanding of the factors that affect flame retardant addition. This study was only a preliminary analysis and could be expanded upon to get more detailed relationships between stores and labels. More research needs to be done on the health effects of Firemaster 550 and Chlorinated Tris as well as on the rate and amount of leeching that occurs with the chemicals. These chemicals are slowly getting more ubiquitous in our environment, and a better understanding of their mechanisms and health effects are needed in order for consumers to better protect themselves and make safer purchases. There also needs to be epidemiological studies to look at the long term health effects of sleeping on treated foam products.

Broader Implications

Not much is known about Firemaster 550 and Chlorinated Tris. As such finding all of these chemicals in the products shows that there is an issue with the laws and the knowledge available to the manufacturers on flame retardants. This is especially concerning because it has been shown that around 40% of the furniture outside of California meets the strict and flame retardant dependent standard: TB 117, even though the law does not apply to them (Rhor 2005). Even CPSC published a risk assessment that deems the flame retardants unsafe (Babich et al 2006).

The findings from this study could be used to change both consumer purchases and manufacturing practices. Recently, a study on car seats by Healthystuff.org found that many of the car seats contain harmful flame retardants, lead and other chemicals (HealthyStuff, 2011). The organization published this data and, soon after, press releases from major manufacturer car seat manufacturers came out saying that they are dedicated to making safe products that both meet the government standards and are safe for children (HealthyStuff 2012). Similar action could result from the release of the data found in the study through the Green Science Policy Institute. Alternatively, the study can also spark consumer awareness and demand for more knowledge of the chemicals that go into our consumer products, pushing forward a healthier and brighter future.

There are many alternative means to meet the flammability standards instead of adding flame retardants such as a change in the product design but there needs to be a push in that direction. We still do not know the long term consequences of halogenated flame retardants like Firemaster 550 and Chlorinated Tris's presence in our furniture and yet every day hundreds of thousands of children and adults are sleeping on mattress pads or sleeping mats and are exposed to these toxic chemicals. Flame retardants seem cost-efficient and effective but we need further research on their long term health effects before we can deem them safe to use.

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APPENDIX A

Statistical formulas for use in thesis

```
Logit<-
glm(P~as.factor(On)+as.factor(Res)+as.factor(Cos)+as.factor(Tar)+as.factor(Wa
l)+as.factor(Ike)+as.factor(JCP)+as.factor(Tue)+as.factor(Bed)+as.factor(Mac)
+as.factor(DK),family=binomial(logit), data=Dataset)
```

“Dataset” refers to one of the 4 datasets created.