Human Exposure to Flame Retardant Chemicals and Health Concerns

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Good morning. I wish to thank Senator Lautenberg and the other members of this Committee for inviting me to testify today. I am Heather Stapleton, an associate professor of environmental chemistry at Duke University. Since 2001 I have worked closely with a team of researchers investigating the sources, fate, and effects of flame retardant chemicals in the environment, in addition to monitoring human exposure to these chemicals. Through these unique collaborations we have accumulated much information on flame retardants that has helped us to better understand the potential hazards of these chemicals, which can now be weighed against their purported benefits. Today I'd like to talk to you about flame retardants, my research, and what we know about health risks to humans.

Human Health Studies. According to research conducted by the Centers for Disease Control and Prevention, 99% of the US population has flame retardant chemicals in their bodies[1], and US adults have body burdens that are an order of magnitude higher than levels in European and Asian countries[2]. Studies have also shown that children clearly have much higher exposures and body burdens of flame retardants compared to adults [1,3,4].

Over the past 5 years, several studies have observed associations between a specific class of flame retardants called polybrominated diphenyl ethers (or PBDEs), and adverse health effects among the US population. Most notably were two recent US studies that found that higher concentrations of PBDEs in infants at birth are associated with reductions in IQ and deficits in gross and fine motor skills later in childhood, and reduction in a women's capacity to become pregnant[5,6]. Other studies have shown that PBDE levels in maternal tissues during pregnancy are associated with increased risk of undescended testicles in male infants, and lower birth weights and head size in newborns[7-9]. Decreases in birth weight are a significant concern as low birth weights in infants predisposes children to more health problems later in life. In addition, PBDE levels in adults have been associated with significant alterations in thyroid hormone levels[10-12]. While none of these studies are definitive, it should be noted that they examined exposures occurring among the general population, and if true, many Americans may be affected.

Unfortunately, no studies have yet examined human health effects related to newer flame retardants used as replacements for PBDEs in consumer products, and which are now found in almost all homes (see exposure section below).

Human Exposure to Flame Retardants. In the late 1990s, mounting evidence began to demonstrate that PBDEs were increasing in human tissues and the environment [2,13]. Furthermore these chemicals were found to be capable of concentrating in tissues following exposure[14], and were estimated to persist in the environment for decades [2]. They are now ubiquitous in our environment as they are very resistant to degradation and can be transported long distances in the atmosphere.

Exposure to PBDEs results from both diet and indoor exposures primarily from dust. Due to their ubiquity in the environment, PBDEs have been detected at low levels in fruits, vegetables, meat, dairy and seafood items.[15,16] However, exposure assessments conducted by the EPA suggest that only 17 % of an adult's exposure to PBDEs is from the diet and 66 % is from dust, whereas in children more than 95% is from dust exposure[17]. More recent studies have confirmed that exposure to house dust particles contaminated with PBDEs is a significant pathway by which people are exposed to PBDEs[18-20], but we have not been able to determine from where the PBDEs in the dust originated. Most researchers assume that treated sources in the home (e.g. furniture, TVs, etc), contribute to this exposure, and our data does suggest that treated furniture and TVs are significantly associated with PBDE levels in indoor dust[21]. However, simple physical examination of the product and/or its labels will not tell us whether or not a product is treated with PBDEs. The only current way to determine whether or not a product is treated with a specific flame retardant is to take a sample of the product and chemically analyze it in a laboratory, a very expensive and laborious process.

Over the past six years my research group has examined human exposure to PBDEs, and other flame retardant chemicals, in indoor environments. As part of this research we have analyzed several hundred samples of indoor dust, including samples from bedrooms, main living areas and car interiors. To date I have not found **one** dust sample that does NOT contain PBDEs. Every home we have tested contains PBDEs, and the levels in indoor dust can vary by a factor of a million. For reasons we do not yet fully understand, some people have very low levels of PBDEs in their homes (parts per billion), while other people have very high levels (parts per thousand). Our studies have also shown that people with high levels of PBDEs in their dust, will most likely have high levels in their bodies[19,20].

More recently we have investigated exposure of toddler's to PBDEs[20]. Using a novel approach, we wiped the surface of children's hands to determine if PBDEs were present on their skin. We found that PBDEs were present on 98% of children's hands, and levels of PBDEs on the hands were highly related to the concentrations of PBDEs measured in their bloodstream. This suggests than children ingest PBDEs from hand to mouth contact, which is typical in young children. EPA studies have demonstrated that toddlers may place their hands in their mouth 18 times/hour on average[22]. The PBDE levels on the children's hands most likely results from contact with the dust in their homes, or perhaps direct contact with treated products. We also found that children from lower socioeconomic backgrounds had levels of PBDEs in their blood that were two times higher than white children born to more educated parents. At present, reasons for this difference are unclear.

Since identifying the new use flame retardants in infant products and furniture (see next section), we have started conducting measurements on these new chemicals in indoor dust, and are developing methods to measure concentrations in human serum and urine. Of particular interest to us is a PBDE replacement chemical called "chlorinated tris" or TDCPP. TDCPP is a suspected carcinogen according to the Consumer Product Safety Commission[23] and is listed as a cancer-causing chemical under California's Proposition 65. TDCPP was once applied as a flame retardant to children's pajamas during the 1970s. However, studies found that a closely related brominated flame retardant was a mutagen, was absorbed through children's skin, and its metabolites were detected in urine[24-26]. TDCPP was also identified as a mutagen and was voluntarily phased out from use in children's sleepwear. Our research now indicates that TDCPP is also present in dust samples, as are the components of a second flame retardant mixture called Firemaster 550 (FM 550). Similar to PBDEs, TDCPP and FM 550 are present in more than 95% of the indoor dust samples analyzed, and levels are equivalent to, or in some cases higher than, levels of PBDEs.[27,28] Therefore, daily exposure to these new flame retardants is expected to be very similar to PBDE exposure among the general population. In addition, we have identified the primary metabolite of TDCPP in more than 98% of human urine samples analyzed to date[29] (and unpublished data), confirming to us that chronic daily exposure to TDCPP is occurring. This suggests children are presently receiving exposure to mixtures of these flame retardants, which may be a concern in light of the neurodevelopmental toxicities associated with some of these chemicals (see toxicity section below) and the observed increase in neurodevelopmental disorders occurring in US children (e.g. autism, ADHD, etc). This highlights a critical need for labeling information on commercial products so consumers can make informed decision about the risks they want to take.

While our research group is working very hard to measure human exposure to these flame retardants from contact with indoor dust, no studies to date have investigated an infant's exposure to flame retardants found in baby products. Because a majority of the infant products are treated with flame retardants (typically TDCPP), and because infants spend almost 24 hours each day in intimate contact with many of these products, studies must be conducted to measure potential exposure to these chemicals. Infants are very vulnerable to toxic exposures as they are still rapidly developing, particularly their brain, making them more vulnerable to effects from toxic chemicals. Inhalation and skin absorption may be significant routes of exposure to some of the chemicals which have not been assessed. A study conducted by the Consumer Product Safety Commission (CPSC), evaluated children's exposure to TDCPP from assumed use in residential furniture and estimated that exposure levels were 5 times higher than the acceptable daily exposure level.[23] The report did not consider potential exposure from contact with infant products, which may be greater than exposure from residential furniture alone.

Products Containing Flame Retardants: For more than 30 years additive flame retardants have been applied to various types of products, including children's pajamas, furniture, electronic items (e.g. TVs, computers, cell phones, DVD players, etc), textiles (e.g. curtains, upholstery), and common building materials (e.g. wiring, insulation, etc). There are various state and federal flammability codes or standards that have led to the use of these chemicals in different types of commercial products, and in transportation equipment (e.g. airplanes, trains, sub-ways, automobiles, etc). The type of chemical used to flame retard a specific material or product will depend upon several variables, including the type of material being treated, the availability and cost of the chemical flame retardants, and the specific standard that is trying to be met.

The chemical structures of flame retardant additives used in consumer products are often proprietary; when submitting pre-manufacture notices to the EPA, the chemical companies must reveal the chemical structures to the EPA, but can declare the structures confidential business information (CBI), which protects that information from being released to the general public. This practice has resulted in large data gaps in our understanding of flame-retardant uses, application levels, and potential sources of human exposure. Through my personal communications with polyurethane foam manufacturers in the US (who produce foam for furniture manufacturers), I have learned that foam manufacturers themselves often do not know the specific chemicals used in the flame retardant formulations they purchase and apply to their foam. This lack of transparency and communication means that academic researchers, and the general public, have trouble understanding if and how people are exposed to these types of chemicals.

The lack of transparency in flame retardant use and applications motivated my collaborators and I to conduct research on consumer products to determine how often flame retardants are used and at what levels. Due to the concerns mentioned above, two of the three PBDE commercial mixtures were voluntarily phased out from production in the US starting in 2005. However, the flammability standards still remain, and thus new flame retardant chemicals have been introduced into consumer products as PBDE replacements. When this phase-out went into effect in 2005, there was no information available on the chemical replacements. Therefore, my collaborators and I started a research project to identify products that contain flame retardants and which may be sources of human exposure, to better understand potential health risks. In 2009 we initiated a study investigating flame retardant use in infant products that contain polyurethane foam, including car seats, nursing pillows, infant sleep positioners, portable mattresses, and changing table pads. We used advanced analytical methods to test 101 different products that were either in use by families at that time, or were purchased new. We found that more than 80% of the products contained a flame retardant we could identify at levels that were approximately 3 to 4% by weight of the foam[30]. PBDEs were found in 5% of the products tested; however, all products containing PBDEs were purchased prior to the 2005 phase out of PBDEs. The most commonly detected flame retardant identified in infant products was TDCPP, and the second most common was FM 550. From our research it appears that TDCPP is still widely used as a flame retardant in furniture and infant products. The other flame retardant chemicals identified in the infant products have little to no health data available, but are similar in structure to chemicals that have known toxicity. These points highlight what I call the "chemical conveyer belt". When one chemical is phased out, another similar chemical is often used as a replacement and we know less about its potential health effects and exposure than the chemical it replaced. History has shown that it often takes millions of taxpayers dollars and several decades of research on these new chemicals before we realize there is a health hazard. This Committee should, in my opinion, consider how this process could be reformed.

The flame retardant standard driving the use of these chemicals in infant products, and in most residential furniture, is a California flammability standard known as Technical Bulletin 117 (TB 117). TB 117 was initiated in 1975 due to increased concerns about house fires that were started by small open flames (e.g. candles). While this standard only applies to furniture sold in the state of California, it appears to have become a de facto standard across the U.S. More recently my colleagues and I have tested foam collected from 102 different couches purchased from around the U.S. between 1985 and 2010. Our findings are very similar to the infant study mentioned above. In this case 85% of the samples contained a flame retardant chemical, even when most couches were purchased outside the state of California. While PBDEs were the most common flame retardant detected in furniture purchased prior to 2005 (the PBDE phase out date), TDCPP was again the primary flame retardant identified in samples purchased after 2005, at levels that were typically 4% by weight of the foam. Furthermore, we spent several months using very advanced analytical equipment to determine the chemical structures of unknown flame retardants detected in 10 of the samples. As with our earlier study, we could find no published health information or toxicity testing for the new flame retardant chemicals we identified in residential couches. Now that these new chemicals have been identified we can begin to measure the extent of exposure among the general public and determine whether or not any adverse health effects are associated with this exposure. Of course, it might be better public health policy to rigorously examine the safety of these compounds before they are put into the products found in the homes of hundreds of millions of Americans.

Toxicity Studies in Animals. Several review papers have been published highlighting an abundant scientific literature on effects of PBDE flame retardants collected from animal studies. These papers demonstrate that PBDEs have effects on hormone levels, reproduction potential, behavior, and learning and memory functions[31-33]. The most significant health effects in animals appear to be related to effects on hormone regulation, suggesting they can function as an endocrine disruptor. PBDEs have a chemical structure that is very similar to thyroid hormones, most notably thyroxine (T4). In laboratory animal studies, PBDE exposures have been shown to negatively affect thyroid hormone regulation most notably by decreasing levels of thyroid hormones in the blood[14,34,35]. Thyroid hormones are critical for growth and development, particularly proper brain development; therefore some limited human health studies have focused on examining associations between PBDE exposure and neurodevelopmental outcomes in children.

While a great amount of effort has been spent examining the toxicity of PBDEs, comparatively little to no research has been conducted on the newer flame retardant chemicals that are being used as PBDE replacements, and that are now found in consumer products. As mentioned earlier, TDCPP was a flame retardant used in children's pajamas during the late 1970s, and then discontinued after studies demonstrated that TDCPP was a mutagen, and therefore a suspected carcinogen. Studies conducted by the National Toxicology Program have also demonstrated that long term exposure to TDCPP in rodents results in increases in tumor formation[36]. More recent studies have also found that TDCPP may affect brain development. Using cells grown in the lab, we recently determined that TDCPP has the same potential as a restricted pesticide called chlorpyrifos, to disrupt the growth and function of young brain cells[37], key factors in brain development. In addition, in a very recent study conducted by my colleagues and I, we found that exposure to FM 550 in rodents resulted in significant changes in hormone levels, advanced puberty, altered behavior, and obesity at exposure levels that were more than 10 fold LOWER than what Great Lakes Chemical cited as the lowest dose at which adverse effects would be observed [38].

Communications Received from the General Public. Many of these human health studies have been highlighted in the news media, increasing the public's concern about exposure to these chemicals, particularly among pregnant women. As a scientist intimately involved in these studies, I have received more than 100 email and phone call communications asking for help in locating products that are not treated with these chemicals. As stated earlier, these products are not labeled with any information indicating whether or not they are treated with flame retardant chemicals. The only way an average consumer could gather more information on chemical treatments in a specific product is to try and contact the manufacturers themselves. Unfortunately, the manufacturers do not always have a clear answer. For example, here is an excerpt of an email I received last week from a consumer trying to locate residential furniture that was not treated with flame retardants:

> "I have called and called and 98% of the manufactures simply don't know anything. One says no but how do I believe them when I have another company telling me it is required in all sofas even outside of California. …. one says no we don't while the local dealer says yes we do [add flame retardants] so I get so many conflicting stories."

This example highlights the frustrations of many Americans. Despite the fact that the California residential furniture flammability standard (TB 117) only applies to furniture sold in California, most furniture manufacturers prefer to use this standard nationwide for ease of production and marketing, and thus manufacture all their products accordingly.

Through my conversations with both the media and the public I am often been asked how I reduce my exposure in my home and what types of products I use in my own home, since I myself am a mother of two young children ages 1 and 3. In my case, I avoid products which our studies have shown to be treated with flame retardants, and I have spent considerable time searching for an alternative product that is not treated. Fortunately, I have managed to find flame retardant free products for all of my baby products with the exception of our car seats, which may need to meet additional standards for automobiles. The furniture I use in my home was manufactured in Italy, and does not meet TB 117 standards. In addition to these steps, my husband and I have chosen to limit carpeting in our homes, which can be laden with flame retardants in the padding, and also leads to dust accumulation in homes. I also wash my hands and my children's hands frequently. Just like the common cold, we can reduce our exposure to these chemicals by simply washing ones hands [39]. As both a scientist and a mother, it is important to me that I reduce my family's exposure to these chemicals.

In closing I would like to urge this Committee to strongly consider legislation that would reduce our children's exposure to these chemicals, some of which are suspected carcinogens, which can be done without compromising fire safety. I have dedicated much of my scientific career to testing consumer products for these chemicals to provide information on potential sources in the home. In my opinion, these products should be labeled to indicate they are treated with these chemicals, to allow consumers a choice, particularly when it involves the use of suspected carcinogens in baby products. Lastly I would just like to note that my research has been funded by the National Institute of Environmental Health Sciences and the National Science Foundation and I thank you for considering my testimony.

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