FLAME RETARDANTS

THE CASE FOR POLICY CHANGE






ENVIRONMENT & HUMAN HEALTH, INC.

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I. Overview

This report examines the history of flame-retardants, as well as the environmental and human health threats they pose.

Synthetic flame-retardants are now globally dispersed and are present in the tissues of most humans who have been tested.

- Flame-retardants include a mixture of several hundred synthetic chemicals added to tens of thousands of commercial products. They are added to plastics, building materials, furnishings, some clothing and textiles, wiring, and electronics such as computers, phones, and appliances.

- Flame-retardants are particularly concentrated in plastics used in planes, autos, and trains. Our buildings are flame-retardant reservoirs that will last for generations. When commercial products and buildings reach the end of their useful life, they are buried or incinerated along with the retardants within them.

- Many flame-retardants are not chemically bound to other product ingredients, meaning that they may be released to both indoor and outdoor environments. Because many of these chemicals break down very slowly—some take many decades to decompose—they pose a risk of exposure for generations.

- Some brominated and chlorinated compounds tend to be *lipophilic,* meaning that they bind to fats in fish, animals, and humans.

They also accumulate in both marine and terrestrial food chains, concentrating in meat, fish, and dairy products. They also enter the human food chain from plastic packaging or processing techniques.

- Since humans sit at the top of marine, plant, and animal food chains, human concentrations are often higher than those of other species.
- Flame-retardant residues are also present in house dust, and in many tested samples of drinking water. Scientists have routinely found flame-retardants in outdoor and indoor air, rain, snow, and polar ice, demonstrating their global circulation.
- Although we focus on the Toxic Substance Control Act (TSCA) and its defects, we also find that the Environmental Protection Agency (EPA) has long neglected these persistent pollutants, despite considerable authority available to the agency to demand testing and control.
- Most of these chemicals have escaped federal regulation, and have been largely neglected by the Food and Drug Administration (FDA), the Consumer Product Safety Commission (CPSC), and the U.S. Department of Agriculture (USDA).
- The European Union has made far more progress than the United States in regulating and identifying these persistent chemicals.
- The U.S. failure to ratify the Stockholm Convention on Persistent Organic Pollutants (POPs) demonstrates further neglect. Chemical companies in many countries manufacture flame-retardants, and the products that contain them are traded around the world. The globalization of this problem makes it especially challenging.

Since humans sit at the top of marine, plant, and animal food chains, human concentrations are often higher than those of other species.

II. Dimensions of the Problem

The global market for flame-retardant chemicals, estimated to be worth $4.8 billion in 2011, will reach $7 billion by 2017.

Flame-Retardant Production and Use

- Today, dozens of companies manufacture or import nearly 2.5 billion pounds of fire-retardant chemicals each year in the United States.
- Worldwide production doubled from an estimated 660,000 tons in 1992 to 1,341,000 tons in 2001.[1]
- As of 2013, production is estimated to be nearly 1.5 million tons, including nearly 200 distinct chemicals. The global market for flame-retardant chemicals, estimated to be worth $4.8 billion in 2011, will reach $7 billion by 2017.[2]
- The Asia-Pacific region (China, India, Japan, and Southeast Asia) accounts for nearly half of the current overall market and is the fastest-growing region in both flame-retardant production and consumption.[3]

- The United States is home to four of the seven largest producers of flame-retardants.[4] These include Albemarle Corp. (U.S.), Chemtura Corp. (U.S.), Dow Chemical Company (U.S.), DuPont (U.S.), Clariant AG (Switzerland), Bayer (Germany), and Israel Chemicals (Israel).

World Consumption of Flame Retardants, 2010

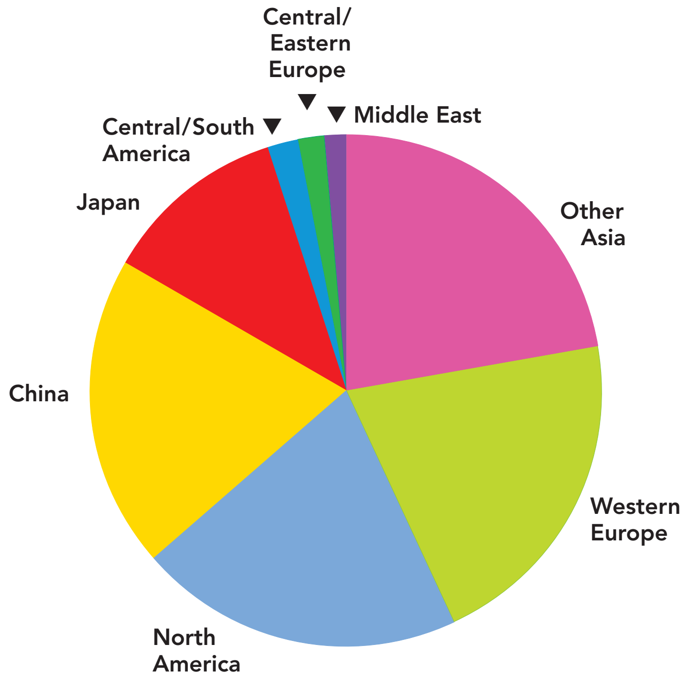
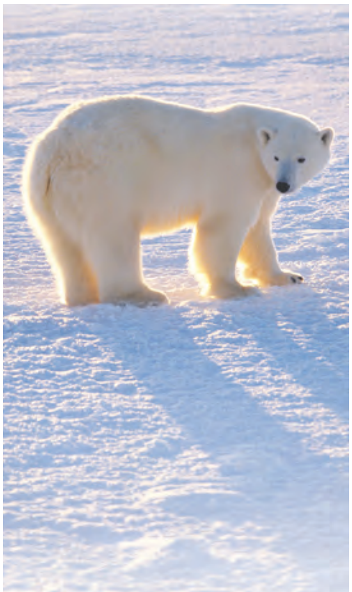


FIGURE 1
Source: http://www.ihs.com/products/ chemical/planning/scup/flame-retardants.aspx

Persistence, Mobility, and Ultimate Fate of Flame-Retardants

- Most flame-retardants are highly persistent, and they move freely from our buildings, furnishings, and appliances into dust that we breathe. Chemical persistence, an important indicator of danger to health, is widely misunderstood.

- The "half-life" of a chemical is the amount of time it takes a chemical released into the environment to degrade to half of its original concentration. The overwhelming majority of complex organic molecules have half-lives of hours or days.



Flame-retardants are now detectable in whales, in polar bears, and in many species of fish and marine mammals, demonstrating the global scale of movement and contamination.

This is the case for most registered pesticide products. During the 20th century, we gradually banned from agricultural use the more persistent elements and compounds, including lead, mercury, arsenic, DDT, aldrin, dieldrin, and chlordane.

- The halogenated retardants containing chlorine or bromine have half-lives from months to nearly a decade.
- Once buried as waste, flame-retardants move through soil as rainfall percolates underground to contaminate both ground and surface waters. Residues of flame-retardants persist in sewage treatment effluent released into rivers, lakes, and oceans.
- Once released to the outdoor environment, flame-retardants tend to concentrate, or "bioaccumulate," as they bind to fats in aquatic life, plants, animals, and marine species. They become more concentrated as they move higher along predators' food chains.
- Flame-retardants are now detectable in whales, in polar bears, and in many species of fish and marine mammals, demonstrating the global scale of movement and contamination. Because humans sit at the top of both plant and animal food chains, we are exposed to higher concentrations than are most other species.

Health Hazards & Susceptibility

- Recent toxicological studies demonstrate that flame-retardants pose the greatest risk to the normal growth and development of fetuses, infants, and small children.
- Flame-retardants cross the pregnant woman's placenta and circulate in fetal tissues. They change the biochemistry, electronic signaling, and normal function of the nervous and endocrine systems that are essential for cognition, memory, learning, and reproductive success.

- The highest concentrations of flame-retardants have been detected in the youngest in our society, with levels often many times the average concentrations found in adults.

- Not only do children have heightened exposures, but they also have heightened susceptibility—a dangerous combination. When mothers breast-feed, their rich, fatty milk carries flame-retardants to their newborns, where the chemicals bind to the babies' fat cells.

The Influence of the Tobacco Industry

- The tobacco industry played a large role in the widespread use of flame-retardants in commercial products. The cigarette manufacturers faced pressure from lawmakers and public health professionals to make cigarettes less flammable, because cigarettes were the cause of many fires.

- The cigarette industry worried that making its products less flammable would change their taste, so the industry lobbied lawmakers to make sure that the flame-retardants were placed in commercial products rather than in cigarettes.

- The tobacco industry provided funding to the National Association of State Fire Marshals to advocate on behalf of the chemical industry to incorporate synthetic flame-retardant chemicals, not in tobacco products, but in many products and materials in the built environment. For example, a sofa with polyurethane foam pillows may contain two pounds of halogenated retardants, nearly 10 percent of the foam's mass.

- Since the flame-retardants are not chemically bound to the foam, but added during mixing, when the foam breaks down from repeated compression and expansion, the flame-retardants escape

The cigarette industry worried that making their products less flammable would change their taste, so the industry lobbied lawmakers to make sure that the flame-retardants were placed in commercial products rather than in cigarettes.

Many residences contain polyvinyl chloride water and waste piping, and several thousand feet of electrical cables, many wrapped in plastic sheathing.

from the pores of the fabric, float through the air, and eventually settle into dust on other furnishings or the floor. From there, they may become airborne and be inhaled, or they can easily be ingested as dust by infants and toddlers who commonly crawl on floors and continuously bring their hands and objects to their mouths.

Flame-Retardants Are Added to Plastics

- The rapid growth of the plastics industry during the mid-20th century changed the material composition of built environments. Many homes today are constructed with plastic siding and sheathing, and contain polyurethane foam insulation.

- Many residences contain polyvinyl chloride water and waste piping, and several thousand feet of electrical cables, many wrapped in plastic sheathing.

- Furnishings and textiles often contain polymers, including curtains and wallpapers, polyurethane foam sofas, bedding, pillows, and many types of clothing.

- Most homes now comprise a diverse collection of electronics, including polycarbonate and polystyrene computers, tablets, phones, games, televisions, battery packs, and power transformers.

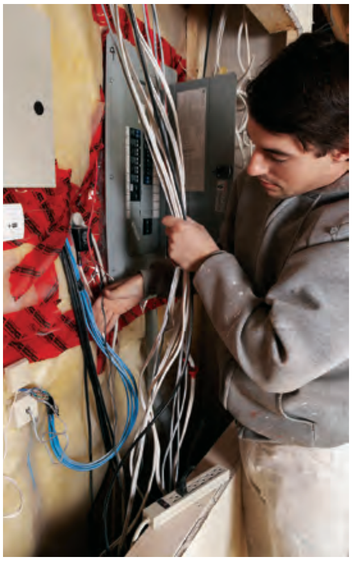
- Although plastics manufacturers did not intend to make buildings more flammable, this surely has occurred. Since plastics are carbon-rich and derived from petroleum by-products, they are highly flammable. Once ignited, some polymers, such as polyurethane foam, yield unusually intense heat and highly toxic fumes.

- This all explains why the building and construction industry, motivated by fire safety regulations and standards, is currently the largest market for flame-retardant chemicals.[5]

- The plastic industry's intent has been to make inexpensive, durable, lightweight, and moldable products. However, these firms did not anticipate how their inventions would change the chemical composition of the environment—and more important, the biochemistry and hormonal activity of the human body.

- The model of chemical innovation has long been to design and sell chemicals that provide some functional benefit. Surprisingly, the plastics industry saw no need to test these chemicals or to understand their safety before selling them.

- In addition, flame-retardants were not tested for their potential to be transported in the air, water, oceans, or soils. Perhaps this is because industry could not predict the magnitude and diversity of future use in tens of thousands of consumer products.



The building and construction industry . . . is currently the largest market for flame-retardant chemicals.

The Failure of the Toxic Substance Control Act

Defects in Federal Law and Regulation

- The primary reason for nationwide contamination by flame-retardants can be attributed to the failure of the Toxic Substance Control Act (TSCA).

- Chemical companies in the United States have had no legal obligation to inform the government about the health or environmental hazards associated with flame-retardants. Testing of chemicals prior to their market introduction has never been required.

- Industry has not been mandated to report flame-retardants' manufacturing volume, chemical mixtures, chemical persistence once products containing them are discarded, their capacity to move through local and global environments, their potential to contaminate food, water, or other species, or any threat they might pose to human health.

In the building trades, those who construct our homes, offices, schools, or shopping malls are not legally responsible for the ultimate fate of building materials or their chemical ingredients.

- Government has not required industry to label products containing hazardous ingredients. In the building trades, those who construct our homes, offices, schools, or shopping malls are not legally responsible for the ultimate fate of building materials or their chemical ingredients.[6]

- TSCA requires EPA to have convincing evidence of significant risk *before* it can require manufacturers to submit necessary environmental and health-effect data prior to selling a new commercial chemical.

- EPA may predict the behavior and effect of compounds based upon their chemical structure and properties, such as molecular weight, water solubility, and lipophilicity.

- TSCA, however, demands stronger evidence. This constraint has become a "catch-22" requirement because EPA needs strong evidence of hazard in order to demand additional data, which has inoculated the industry from further regulation.

- Despite widespread understanding of this defect, nothing has changed in the legal requirement in nearly 37 years. Thus, the commercial chemical industry has been free to market more than 80,000 chemicals, 90 percent of which were untested for health and environmental effects when they were introduced.

- Pesticide manufacturers are required to test the environmental behavior and toxicity of new products extensively *before* they request EPA approval to market the new products. On the contrary, there is no requirement for pre-market scientific testing of flame-retardants by producers, manufacturers, and/or EPA. Today, even if a chemical company has tested its commercial chemicals, it has no legal obligation under TSCA to forward the results to any regulatory agency.

- EPA has not relied on the authority provided by other key environmental statutes to prevent flame-retardant residues in groundwater, drinking water, and sewage effluent; in outdoor air; in solid, liquid and hazardous wastes; in many species of plants, wildlife, fish, and endangered species; and in food and human tissues.

- EPA has not invoked the Safe Drinking Water Act, the Clean Water Act, the Clean Air Act, the Resource Conservation and Recovery Act and even the Endangered Species Act to prevent additional contamination and to compel cleanup.

- Belatedly, in March of 2013, EPA announced that it would conduct risk assessments for four flame-retardant chemicals under TSCA authority. These flame-retardants—TBB, TBPH, TCEP and HBCD—are already ubiquitous in our lives. They are in household furniture, home insulation, electronic equipment, children's foam products, bedding, automobiles, and even our food. Conducting risk assessments decades after a chemical has been introduced into the marketplace occurs too often in this country.

Abbreviations

TBB 2-Ethylhexyl ester 2,3,4,5-tetra-bromobenzoate
Used in PVC and neoprene, wire and cable insulation, and coated fabric.

TBPH 1,2-Ethylhexyl 3,4,5,6-tetra-bromobenzene-dicarboxylate, or (2-ethylhexyl)-3,4,5,6 tetrabromophthalate
Used in polyurethane foam in furniture and juvenile products.

TCEP Tris(2-chloroethyl) phosphate
Used in furniture foam, PVC vinyl, home electronics, adhesives, rubber, upholstery, carpet backings, plastics, paints and varnishes.

HBCD Hexabromo-cyclododecane
Used in thermal insulation foams and textile coatings.

Source: *EPA. http://www.epa.gov/oppt/existingchemicals/pubs/2013wpractivities.html.*

Human negligence is the overwhelming cause of fires.... There is little evidence that fire-retardant chemicals have led to a significant decrease in either deaths or harm due to fire.

Substituting One Hazard for Another

- The history of flame-retardants demonstrates a problematic pattern that has taken place in a number of stages and over time.
  - The first stage has been the widespread adoption and use of new fire-retardant products without premarket testing to determine their environmental behavior or health effects.
  - The second stage has involved the scientific community gradually learning of the dangers of the new fire-retardants.
  - The third stage often happens years later when public interest groups clamor for the phaseout of fire-retardants that have already been in use for decades.
  - The fourth stage occurs when manufacturers reach their 20-year patent life, and have designed a new fire-retardant to replace the offensive one.

- The fifth stage occurs when new flame-retardants are introduced yet again without environmental and health testing, and so the cycle continues.

- A brief review of the earliest flame-retardants' history reveals the pattern outlined above. Flame-retardants include asbestos, PCBs, PBBs, PBDEs, as well as the more recent brominated and organic phosphorous compounds.

- For more information on newer fire-retardants that have replaced earlier chemicals now known to be harmful to human health and the environment, see page 23, "Substituting One Flame-Retardant Hazard for Another."

Abbreviations

PCBs Polychlorinated biphenyls, banned in 1977. Used in electrical equipment.

PBBs Polybrominated biphenyls (PBBs) were added to plastics and textiles.

PBDEs Polybrominated diphenyl ethers (PBDEs) were added to plastics and foam products.

Source: *ATSDR. (2001). ToxFAQs. http://www.atsdr.cdc.gov/toxfaqs.*

Most Fires Are Preventable Without Chemical Fire-Retardants

- Human negligence is the overwhelming cause of fires. In the United States, the primary sources of indoor fires are faulty or overloaded electrical wiring, untended kitchen stoves, poorly vented heating appliances, and careless use of tobacco products, mainly cigarettes.[6]

- There is little evidence that fire-retardant chemicals have led to a significant decrease in either deaths or harm due to fire. However, other factors may also have contributed to the decline in loss of life and property.

- Increased use of smoke detectors, alarms and sprinklers; reductions in cigarette consumption; improved building techniques; fire and electrical codes; insurance requirements for smoke alarms, and improved firefighter training have all led to a reduction in fire deaths.[7 8]

There is insufficient evidence to prove that the addition of flame-retardant chemicals to furniture foam or home insulation has resulted in a reduction in fire deaths.

- U.S. fire incidence statistics do not indicate that fireproofing our environments has reduced fire incidence, severity, and loss. For example, there is insufficient evidence to prove that the addition of flame-retardant chemicals to furniture foam or home insulation has resulted in a reduction in fire deaths.

- Smoke inhalation, not burns, causes most fire deaths. In fact, flame-retardants increase the amount of toxic gases produced.[9]

- In states without regulations demanding that additional flame-retardants be added to furniture foam, there were no more fire deaths than in California, where state regulatory standards (TB 117) require additional flame-retardant chemicals to be added to these products.[10] Similarly, little evidence exists to substantiate claims that adding flame-retardants to home insulation has reduced deaths caused by fires.

- Those who oppose adding retardants to home insulation argue that homes already are protected from fires by a thermal wall barrier, fire-resistant sheet rock, and fire-resistant wall coatings, such as epoxy resins, wall coatings, or polyurethane floor finishes.[11]

Waste

- There are no safe disposal options for polyurethane foams that contain halogenated flame-retardants. Incineration can create dioxins and furans; recycling can contaminate the plastic waste stream; and landfilling can lead to leaching of chemicals into soil and potential contamination of the food supply.[12]

- Carpet pads, furniture, and home insulation containing flame-retardants are potential sources of contamination for landfills. Assuming a 30-year average lifetime for foam-containing household furniture and polystyrene insulation, the majority of PBDE-

contaminated furniture and polystyrene insulation has not yet entered the waste stream.

- As insulation boards from construction activities are landfilled or incinerated, exposure to HBCD is forecast to increase.[13] High concentrations of HBCD have been identified near waste disposal sites, including recycling, landfilling, and incineration facilities.[14]
- EPA estimates that in 2009 the U.S. discarded 4.7 billion pounds of televisions, computers, cell phones, printers, scanners, faxes and other electronic waste (e-waste), all of which are likely to have contained flame-retardants.[15]
- About 25 percent of these electronics were collected for recycling, with the remainder disposed primarily in landfills.[16]
- The United States ships most of its electronic waste to China—up to 80 percent in 2008.[17] The disposal of e-waste containing flame-retardants is a growing health concern. Waste disposal is especially problematic in Asian developing countries, where PBDEs and

As insulation boards from construction activities are landfilled or incinerated, exposure to HBCD is forecast to increase. High concentrations of HBCD have been identified near waste disposal sites, including recycling, landfilling, and incineration facilities.

Abbreviations

TBBPA Tetrabromobisphenol A Used in epoxy resin printed circuit boards and as an additive flame-retardant in acrylonitrile-butadiene-styrene (ABS).

Source: http://www.epa.gov/dfe/pubs/projects/pcb/

During recycling, plastics without flame-retardants are melted and mixed with those that contain them, creating a recycled soup of polymers and flame-retardant chemicals.

TBBPA from printed circuit boards is often found within and beneath dumpsites.[18]

- A 2008 study found that people living near an electronic waste site in Asia had higher PBDE concentrations in their blood than a control group.[19] In South China, PBDE-contaminated vegetables around an e-waste dismantling site pose a potential local health risk.[20]

- The absence of any dependable flame-retardant labeling system for consumer products creates a special recycling problem. During recycling, plastics without flame-retardants are melted and mixed with those that contain them, creating a recycled soup of polymers and flame-retardant chemicals. Those purchasing the recycled plastics have little hope of understanding the chemical mixture, which is incorporated into more consumer products.

Fireproofing Our Environments

- Fire management quickly grew to rely on adding flame-retardant synthetic chemicals to our buildings, furnishings, clothing, vehicles, electronics, and the plastics that contain our food and water. It should be no surprise that these chemicals run through our veins, given the volume of flame-retardant production and the tens of thousands of commercial products that contain them.

- There is certainly a need for the strategic use of flame-retardant chemicals in high-fire-risk situations. These include commercial aircraft, marine vessels, cars, electrical wiring, and some appliances; some building materials; structures built in fire-prone arid regions; and some types of textiles and specialized clothing for those facing special fire risks. However, adding untested and unregulated fire-retardants to our built environments and consumer goods has resulted in unnecessary health risks.

III. Substituting One Flame-Retardant Hazard for Another

Asbestos

- Nearly 2000 years ago, the Greeks recognized the fire-resistant properties of asbestos, a natural and fibrous mineral mined from the earth. Slaves who wove the mineral into clothing developed "sickness of the lungs."

- Asbestos was not widely used in the United States until the late 19th century, when it was added to provide insulation for ovens, boilers, steam pipes, and turbines. It was added to corrugated cardboard and commercial papers—uses that are now banned.

- Marine vessels used asbestos as a fire-retardant for much of the 20th century, and it eventually became a common additive in many

Nearly 2000 years ago, the Greeks recognized the fire-resistant properties of asbestos, a natural and fibrous mineral mined from the earth.

After five decades of use, EPA banned PCBs from production, leaving a legacy of contaminated landscapes and waterways.

different building products, including ceiling tiles, insulation, and floor tiles. Asbestos-induced lung disease became prevalent among ship workers and miners. By the 1930s, it was believed to cause asbestosis, leading to cancer.

- The National Institutes of Health and the World Health Organization now classify it as a "known human carcinogen."[21] Few realize that asbestos is not banned in the United States, and it is still allowed in building materials, including roofing and floor tiles, some clothing, and even disc brake pads and linings.[22]

Polychlorinated Biphenols (PCBs)

- PCBs have been produced since 1929 to cool electrical equipment, including power-line transformers present on every street with overhead lines in the United States. During 50 years of manufacture of the chemical, three billion pounds of PCBs were produced for many different industrial applications.[23]
- After five decades of use, EPA banned PCBs from production, leaving a legacy of contaminated landscapes and waterways. PCBs, like their modern chemical relatives, are still found globally in the environment, especially in marine life, and in human bodies.
- The State of New York is still trying to restore segments of the Hudson River, where GE dumped an estimated 1.3 million pounds of the compound.
- Bluefish and striped bass caught in the river and in offshore Atlantic coastal waters accumulate the chemical and deliver a dose of these toxins to anyone who consumes them.
- Recent concerns about the safety of flame-retardants have focused on brominated flame-retardants (BFRs), introduced after concerns were raised about the health effects of PCBs.

- After decades of research, we have learned that PCBs are toxic to the immune system, reproductive organs and the thyroid gland, and also probably cause cancer.

- Children with greater exposure to PCBs have lower birth weights, slower growth rates, and poorer performance on tests of brain development. PCBs continue to migrate from landfills, contaminate fish, and evaporate from contaminated bodies of water.[24]

- Fish consumption, a major route of exposure to PCBs, is correlated with levels of PCBs in breast milk and maternal consumption of contaminated fish.[25]

PCBs continue to migrate from landfills, contaminate fish, and evaporate from contaminated bodies of water.

Brominated Flame-Retardants (BFRs)

Polybrominated Biphenyl (PBB)

- A brominated flame-retardant chemical, PBB, replaced PCBs and was widely used until the 1970s as a flame-retardant in electronics.

- In 1973, one of the largest chemical contamination incidents in U.S. history demonstrated its toxicity. Thousands of pounds of PBB fire-retardant were accidentally mixed with livestock feed in Michigan, poisoning livestock and exposing thousands of Michigan residents to PBB-contaminated meat, dairy products, and eggs.

- Years later, significant exposure-level-related increases in lymphoma and digestive-system cancer were documented.[26] U.S. production of PBBs, now classified as human carcinogens, was voluntarily stopped in 1976 due to concerns over their potential to disrupt the endocrine system.

- In 2003, PBBs were listed among six controlled substances in new electric and electronic equipment under the Restriction of

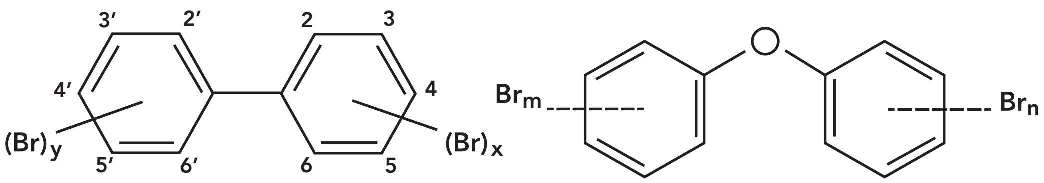
Hazardous Substances Directive (RoHS), enacted into European Law. This directive cites concerns about human exposure, including immunotoxicity and central nervous system disorders seen in animals at low doses; evidence that pre- and post-natal exposure to PBB in girls leads to menarche at an earlier age; and potential cancer risks in humans.[27]

Abbreviations

PBDEs PBDEs are mixtures of similar chemicals called *congeners,* classes of compounds with similar structure and properties. There are over 200 individual PBDE congeners, which often occur in mixtures. The three most widely used mixtures in consumer products are DecaBDE, OctaBDE, and PentaBDE.

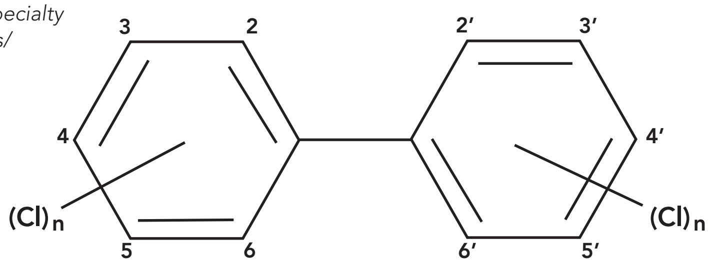
Polybrominated Diphenyl Ethers (PBDEs)

- The chemical industry reacted to the PBB debacle by introducing a new, but structurally similar, family of chemicals—the PBDEs. Note the identical structure of the bromine rings with the only difference being the location of the link between the rings, and the addition of a single oxygen atom in PBDE.



PBB PBDE

Source: *http://www.specialtyanalytical.com/images/img_PBs.jpg*



PCB

Source: *http://www.specialtyanalytical.com/analysis-pcb.php*

PBDE and PBB are structurally similar to polychlorinated biphenyls (PCBs). The difference between PBBs and PCBs is the substitution of bromine for chlorine in PBBs.

- The increase in production and use of plastics and synthetic fibers in the 1970s led to a rapid growth in the demand for PBDEs, especially in polyurethane foam-filled furniture that replaced cotton-filled furniture in the 1970s.

- Promoted as safe by industry, PBDEs were added to furniture, building and construction materials, electronics, and hundreds of plastic products. *The Chicago Tribune's* series "Playing with Fire" documents the role the tobacco industry had during this period in promoting flame-retardants to avoid adding them to tobacco and to deflect the role of cigarettes in home fires.[28]

- From the mid-1970s to 1980s there was a substantial increase in PBDE levels in both sediments and aquatic biota, along with exponentially increasing PBDE levels in mother's milk.

- In 2001, the National Food Association in Sweden raised concerns about PBDEs' persistence, bioaccumulation, toxicity, and lipophilicity. These concerns were followed by studies about the potential of PBDEs to cause a wide range of toxic effects, including effects on thyroid function, neurotoxicity during development, and effects on the immune system.[29]

- Europe was the first to ban two flame-retardants, PentaBDE and OctaBDE, in 2004. Maine, California, and Hawaii followed in 2008. In the same year, Europe and Maine extended their ban to DecaBDE.[30] Industry in 2004 phased out PentaBDE and OctaBDE. Some major manufacturers are phasing out DecaBDE with a 2013 target.

- Despite discontinuation of production by manufacturers, reservoirs of each of these chemicals exist in built environments, textiles, furnishings, and other commercial and industrial facilities. These reservoirs will contribute to additional human exposures for decades.

The increase in production and use of plastics and synthetic fibers in the 1970s led to a rapid growth in the demand for PBDEs, especially in polyurethane foam-filled furniture that replaced cotton-filled furniture in the 1970s.

Parents were alarmed in the mid-1970s to learn that children's sleepwear contained a chemical called "Tris" that was capable of inducing genetic mutations and cancer.

Tris(2,3-dibromopropyl) Phosphate (Tris)

- Demand for new chemical flame-retardants in home furnishings, building construction, and electronics increased in the 1970s and 1980s. In addition, the growth of the synthetic fabrics created a new market for adding flame-retardants to children's clothing.

- Parents were alarmed in the mid-1970s to learn that children's sleep-wear contained a chemical called "Tris" (Tris(2,3-dibromopropyl) Phosphate, or brominated Tris) that was capable of inducing genetic mutations and cancer. This chemical was also capable of being absorbed by their children's bodies.

- The Consumer Product Safety Commission (CPSC) recognized that Tris posed a significant risk to infants and children, and banned it from children's sleepwear in 1977.[31]

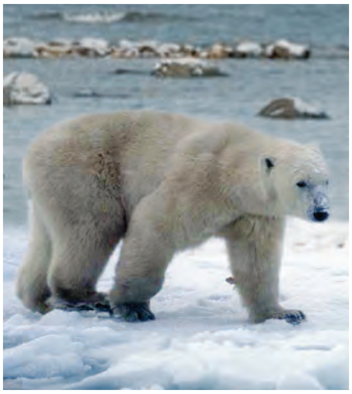
- The CPSC, however, did not ban the chemical from use in other baby products. Tris can still be found in infants' crib mattresses, changing tables, and car seats. Tris is still used as a fire-retardant in couches, chairs, carpet padding, and other home furnishings.[32]

- In 2012, Tris was detected in the house dust of 75 percent of those homes tested.[33]
- Concerns about the health effects of PBDEs and Tris created a market for safer flame-retardants. Like their chemical predecessors, however, the chemicals used as substitutes are also suspected of having detrimental health effects.
- These chemicals, too, have been detected in the Arctic and deep ocean seas. Their similar environmental fate is not a surprise, given that some of the most common substitutes have PBDE-like properties, such as high bromination, low solubility in water, and the ability to leach out of products.

Tetrabromobisphenol A (TBBPA)

- Currently, the most widely used brominated fire-retardant worldwide is TBBPA. It is a chemical substitute for certain PBDEs. It is used in electronic equipment, foam insulation, and adhesives.[34]
- TBBPA is an unlabeled ingredient in some plastics, paper, and textiles, and is commonly applied to carpeting and office furniture.[35] In 2012, the U.S. national production volume was more than 100 million pounds.[36]
- TBBPA exhibits thyroid hormone activity in laboratory studies, induces estrogenic activity in experimental animals, and has been detected in dust in homes and in rooms containing computers and electrical equipment.[37]
- It is detected in human tissues, can cross the placenta, and has been measured in breast milk samples throughout the world.[38]

Tris can still be found in infants' crib mattresses, changing tables, and car seats. Tris is still used as a fire-retardant in couches, chairs, carpet padding, and other home furnishings.



Another PBDE substitute, HBCD, has a strong potential to bioaccumulate and biomagnify. HBCD is toxic to aquatic organisms, persists in air, and is found in remote regions, including the Arctic.

HBCDs "Based on the available evidence, it is concluded that HBCD is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted."
— United Nations.[42]

Hexabromocyclododecane (HBCD)

- Another PBDE substitute, HBCD, has a strong potential to bio-accumulate and biomagnify. HBCD is toxic to aquatic organisms, persists in air, and is found in remote regions, including the Arctic.[39]

- It is the third most commonly produced flame-retardant chemical, and is used primarily in Europe and China. Animal test results indicate that HBCD may cause reproductive, developmental, and neurological effects.[40]

- It is ubiquitous in sediment, plants and animals, as well as in human breast milk, fat and blood. Increasing concentrations in the tissues of California sea lions, harbor porpoises and bird eggs are similar to trends seen for PBDEs, indicating its rising use as a PBDE substitute. HBCD is used primarily in foam insulation to meet fire code requirements.

- The European Union added HBCD to its list of Substances of Very High Concern under its Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) directive in 2012. The Stockholm Convention on Persistent Organic Pollutants listed HBCD for phaseout in May of 2013. However exemptions for foam insulation are part of the agreement with manufacturers.[41]

Firemaster 550

- The newest replacement for PentaBDE in furniture foam is Firemaster 550. A blend of several chemicals, it is now the most common flame-retardant used in California.

- Firemaster 550 was marketed as a safe substitute for PentaBDE that would not escape from treated products. Its manufacturer, Chemtura, includes Firemaster 550 in its Greener Innovation program.[43] However, components of Firemaster 550 have been detected in home dust at increasing levels over the last five years. Concentrations of Firemaster 550's ingredients were higher in dust from California homes in 2011 than in 2006, consistent with its use as a PentaBDE replacement.[44] It has been detected in the air around the Great Lakes and in wildlife around the world.[45]

- Firemaster 550 has recently been implicated as a possible endocrine disruptor and obesogen (obesity-causing chemical). One of Firemaster 550's component chemicals, TBB, was detected in the fat of all the exposed animals and their offspring, indicating it can cross the placenta during pregnancy. It is also found in breast milk.[46]

- The mixture that comprises Firemaster 550—TBPH—is a brominated DEHP, which is associated with health impacts and is listed in California as a known carcinogen and developmental toxin. Firemaster 550 has not been tested for its ability to cause cancer, affect reproduction, or cause developmental issues.

Organophosphate Flame-Retardants

- Use of organophosphate (OP) flame-retardants has increased since the phaseout of PBDEs. OPs are mainly used as additives and are therefore not tightly bound to the products. This means that the added flame-retardants, which are not firmly fixed to the products, can leach into the environment.

- Commonly used organophosphate flame-retardants include:
  - TBEP Tris(2-butoxyethyl) phosphate
  - TCEP Tris(2-chloroethyl) phosphate
  - TCP tricresyl phosphate
  - TCPP Tris(2-chloroisopropyl) phosphate
  - TDCPP Tris(1,3-dichloro-2-propyl) phosphate

The newest replacement for PentaBDE in furniture foam is Firemaster 550. A blend of several chemicals, it is now the most common flame-retardant used in California.

No studies of organo-phosphate (OP) flame-retardants' effects on pregnant women, their fetuses, or children have been conducted.

- No studies of OP flame-retardants' effects on pregnant women, their fetuses, or children have been conducted. Several new studies on OP flame-retardants in animals show reproductive health effects and raise concerns about other unknown health effects.

- In 2012, several OP flame-retardants were detected in airborne particles over the Northern Pacific and Indian Ocean toward the Polar Regions, providing evidence that these chemicals migrate long distances.[47] And in 2013, TCEP was detected for the first time on the Antarctica ice sheet.[48]

Common BFR and OP Flame-Retardants, 2012

Amount Imported or Produced in the United States (MILLIONS OF POUNDS)					
	Not Available	1–10	10–50	50–100	100–500
Brominated Flame-Retardants					
DecaBDE			●		
TBBPA					●
HBCD	●				
FM550	●				
Organophosphate Flame-Retardants					
TDCPP			●		
TCPP				●	
TCEP	●				
TCP		●			
TBEP		●			

TABLE 1
Source: *Chemical Data Access Tool (CDAT). Chemical Data Reporting Information. 2012.*

About 75 different commercial brominated flame-retardants (BFRs) are currently used, or have been used, in consumer products. Each one has different chemical properties and toxicological effects.

IV. Flame-Retardants in Our Daily Lives

- Human exposure to the variety of flame-retardants varies widely throughout the world, depending on country-related legislation, usage, and production of these chemicals.[49]

- Studies suggest that people living in the United States have some of the highest levels of flame-retardants in their bodies. In 2008, the Centers for Disease Control and Prevention (CDC) published data from the National Health and Nutrition Examination Survey (NHANES) depicting, for the first time, U.S. citizens' PBDE blood levels.[50]

- This survey, based on data from blood samples collected in 2003 and 2004, was the first on PBDEs in the United States. A comparison of these data to smaller studies in Europe demonstrates that

Studies suggest that people living in the United States have some of the highest levels of flame-retardants in their bodies.

TABLE 2
Source: *American Chemistry Council. Flame-Retardant Alliance. http://flame-retardants.americanchemistry.com/FR-Basics#How-Do-FRs-Work.*

Where Flame-Retardants Are Often Found

Electronics and Electrical Devices	Consumer electronics (e.g., smart phones, TV sets, DVRs, laptops) Communication and information technology (IT) equipment (e.g., microprocessors, computer servers, modems, printers, copy machines, fax machines, radios) Electrical appliances (refrigerators, vacuum cleaners, clothes dryers, dishwashers) Electrical parts (e.g., connectors, USB ports, plug and socket connectors; switches) Wires and cables (e.g., insulated electrical wires and cables used in EEE consumer and transportation applications such as computer cables, and cables and wiring in automobiles) Transportation, aviation and medical applications (printed wiring boards, computerized dashboards, control panels, diagnostic equipment) Specialty military and aerospace applications
Building and Construction Materials	Electrical wires and cables, including those behind walls Insulation materials (e.g., polystyrene and polyurethane insulation foams) Paints and coatings that are applied to a variety of building materials, including steel structures, metal sheets, wood, plaster and concrete Structural and decorative wood products and fixtures Roofing components Composite panels
Furnishings	Natural and synthetic filling materials and textile fibers Foam upholstery Foam mattresses Curtains and fabric blinds Carpets
Transportation (Airplanes, Trains, Automobiles)	Overhead compartments Seat covers, fillings, headrests and armrests Roof liners Textile carpets and curtains Sidewall and ceiling panels Internal structures, including dashboards and instrument panels Insulation panels Electrical and electronic cable coverings and equipment Battery cases and trays Car bumpers Stereo components, GPS and other computer systems

PBDE blood levels are up to 35 times higher in the United States than in Europe, despite similar levels found in food in both regions, which suggests significant non-food exposure.[51]

- Most of the available data on flame-retardants in our bodies and in our environment measure PBDEs that have been found at rapidly rising levels in humans during the past few decades.[52]
- Despite the phaseout of Penta- and OctaBDE in 2004, their congeners continue to be detected in humans and the environment at increasing levels, possibly due to imported articles containing these compounds and/or their breakdown in the environment.[53]
- Personal habits, dietary preferences, geographic location, and time spent indoors, in cars, and outdoors affect exposure to flame retardants.
- Flame-retardant chemicals are found in our homes, cars, schools, and where we work. They have been detected in products made for babies and children, as well as in our food.

Indoor Sources of Exposure

- Since most Americans spend, on average, 90 percent of their time indoors, understanding sources of indoor exposure to flame-retardant chemicals is important to reducing exposure.[54]
- As semivolatile organic compounds (SVOCs), flame-retardants can migrate from building materials and furniture to indoor air, house dust, and other indoor surfaces. They are found frequently indoors; PBDEs have been detected at significant levels.[55]
- Indoor levels of PBDE flame-retardants vary widely, with the highest concentrations detected in California. Higher levels have been detected indoors in the United States than in Europe.[56]

Flame-retardant chemicals are found in our homes, cars, schools, and where we work. They have been detected in products made for babies and children, as well as in our food.

Bromine Levels in Household Items

TABLE 3
Source: *Imm P, Knobeloch L, Buelow C, Anderson H. Household Exposures to Polybrominated Diphenyl Ethers (PBDEs) in a Wisconsin Cohort. Environ Health Perspect. 2009 December; 117(12): 1890–1895.*

Tested Item	No. of Items Tested	Range Found (mean)
XRF Bromine Readings (ppm)		
Primary vehicle seat	44	7–30,600 (5,463)
Cloth upholstery	32	7–30,600 (7,139)
Leather	11	20–2,669 (288)
All household televisions	98	4–128,300 (94,338)
Mattresses	36	None detected–6,707 (339)
Innerspring	32	None detected–2,282 (98)
Foam	1	8 (no range)
Waterbed	2	18–6,707 (3,362)
Air	1	1,983 (no range)
Mattress pads	32	None detected–14,600 (1,416)
Sleeping pillows	44	None detected–16,400 (1,537)
Polyurethane foam	18	None detected–16,400 (3,646)
Feather	8	None detected–16 (6)
Polyester fiber	18	None detected–1,877 (107)
Living room carpet	38	None detected–718 (130)
Living room sofa	38	None detected–19,400 (2,599)
Office computer	30	None detected–109,000 (31,546)
PBDE levels		
Household dust (ng/g)	38	466–46,883 (5,651)

Bromine, a chemical component of brominated flame-retardants, is used as an indicator of BFR levels found in household items.

- Contamination of indoor environments with flame-retardants, particularly via dust, is considered a significant source of exposure in many areas in the world.[57] House dust can be ingested, inhaled, and absorbed through the skin and is the primary source of exposure to brominated and OP flame-retardants.[58]

- Concentrations of OP flame-retardants in house dust may be of the same order of magnitude as PBDEs, whereas other flame-retardants greatly exceed PBDEs.[59] In the United States, EPA estimates that house dust contributes up to 90 percent of an adult's overall exposure to PBDEs.[60]

- House dust can be a significant exposure pathway for children, who ingest more dust than adults.[61] Ingestion of dust can result in 100-fold higher exposure for a toddlers living in a home with elevated PBDE concentrations.[62] It is the main exposure pathway for all ages other than infants, whose greatest exposure to PBDEs may be via breast milk.[63] But several studies indicate that flame-retardants in dust find their way into breast milk, too.[64]

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Following the phase-out of PentaBDE in furniture foam, new flame-retardants were found to be lurking in U.S. homes. In 2008, California homes still had higher levels of PentaBDEs than the rest of the world.

- Bromine levels, used as indicators of brominated flame-retardant (BFR) levels, vary widely among household items, especially vehicle seats and television sets. A recent study showed that the bromine content of sleeping pillows and vehicle seats was the strongest predictor of blood serum PBDE concentrations.[65]

U.S. Homes

- Early studies on flame-retardants in U.S. homes focused on PBDEs, which, in 2003, were found to be 10 times higher than in Europe. Following the phaseout of PentaBDE in furniture foam, new flame-retardants were found to be lurking in U.S. homes. In 2008, California homes still had higher levels of PentaBDEs than the rest of the world, and also had some of the highest concentrations of OP flame-retardants.

- The only place with higher OP flame-retardant concentrations than California is Japan, where elevated levels are likely due to the phaseout of PentaBDE 20 years ago.[66] A 2009 Boston study found levels of the OP flame-retardant chlorinated Tris (TDCPP), used to treat furniture foam, in house dust at levels comparable to PBDEs.[67]

PBDE House Dust Concentrations: Highest in California

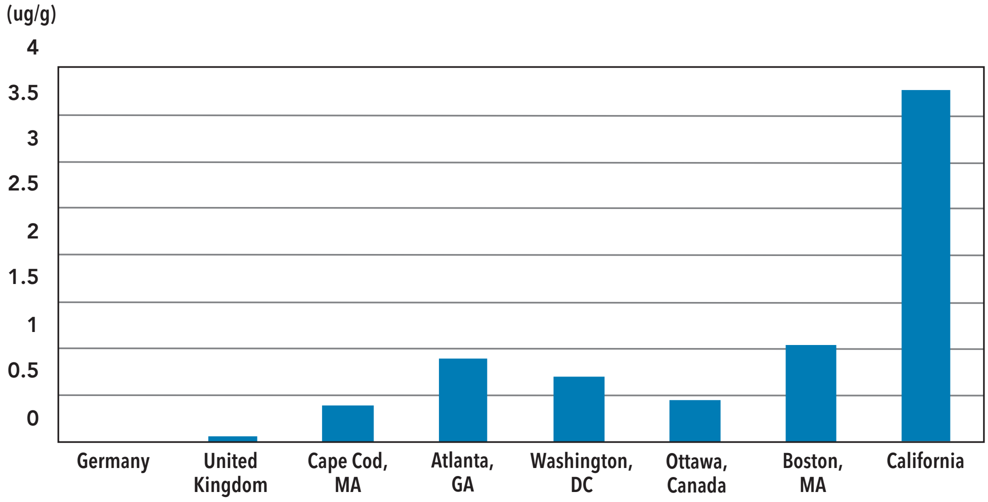


FIGURE 2
Source: *Zota A, Rudel R, Morello-Frosch R et al. Elevated House Dust and Serum Concentrations of PBDEs in California: Unintended Consequences of Furniture Flammability Standards. Environ. Sci. Technol., 2008,10.1021/es801792z and http://greensciencepolicy.org/halogenated-flame-retardant-chemicals.*

- In the last decade, an increasing number of flame-retardants have been detected in U.S. homes. In 2012, the Silent Spring Institute detected 44 different flame-retardant chemicals in household dust; 36 were found in at least 50 percent of the samples, sometimes at levels of health concern.

- Brominated Tris (TDBPP), banned in children's sleepwear in the 1970s and still used in other children's products and electronics, was detected in 75 percent of homes tested. The study found that concentrations of Firemaster 550 components have increased in the last few years, consistent with its use as a substitute for PentaBDE.[68]

Electronics

- Since the 1970s, the electronics industry has been one of the largest consumers of brominated flame-retardants. Manufacturers claim that adding flame-retardants to plastics used in electronics provides an important fire safety benefit, but no data demonstrate these benefits.[69]

- Before its phaseout, OctaBDE was used primarily in electronics. Currently, the most common flame-retardants added to electronic equipment are TBBPA and DecaBDE. In one study, both of these chemicals were detected on every computer sampled.

- Computers are considered a significant source of DecaBDE exposure in the dust of schools, homes, offices, and businesses.[70]

- Electronics may also be an important source of flame-retardants in the home. HBCD, used in electronic equipment, was detected at higher levels in breast milk from Boston mothers with more stereo and video electronics in the home.[71]

Manufacturers claim that adding flame-retardants to plastics used in electronics provides an important fire safety benefit, but no data demonstrate these benefits.

A variety of flame-retardants have been detected in 85 percent of polyurethane foam in residential couches tested, depending on the age of the sofa.

- A 2012 Swedish study found significant correlations between concentrations of some PBDEs and HBCD in air and/or dust and the presence of electronics and electrical devices.[72]

Furniture Foam

- For nearly 40 years, the California flammability standard (TB 117) has required polyurethane foam in upholstered furniture sold in the State of California to withstand exposure to a small open flame for 12 seconds. The standard became a de facto national standard.

- Polyurethane foam was made flame-retardant with an average of 3 percent PentaBDE—sometimes reaching as high as 30 percent by weight—until PBDE was discontinued in 2004.[73]

- PentaBDE was used almost exclusively in flexible polyurethane foam in bed mattresses and in cushioning in upholstered products. In 2003, nearly 8 percent of the more than 2.1 billion pounds of flexible polyurethane foam produced annually in the United States contained PentaBDE.[74]

- After the phaseout of several PBDEs, the use of alternative flame-retardants in foam, including TDCPP and Firemaster 550, increased significantly.[75] A variety of flame-retardants have been detected in 85 percent of polyurethane foam in residential couches tested, depending on the age of the sofa.

- Couches purchased before 2005 contained PBDE (39 percent) and TDCPP (24 percent). The phaseout of PBDE resulted in the increased use of TDCPP (52 percent) and components associated with Firemaster 550 (18 percent) after 2005.[76]

- Some baby products are considered juvenile furniture, and the polyurethane foam used in these products must also comply with TB 117. Infant products containing foam include nursing pillows,

strollers, high chairs, and baby carriers. A 2011 study found that 80 percent of the 101 baby products with foam tested contained a flame-retardant.[77]

Carpets

- While carpets are not required to be treated with flame-retardants, carpet cushions often contain them. Over 12 billion pounds of foam carpet padding, some of which is recycled from furniture and automotive foam, is estimated to be in U.S. homes and offices.[78] From the late 1960s until early 2005, PentaBDE was used in furniture foam and was found in scrap foam used to make carpet cushion.

- New carpet cushion has lower levels of PentaBDE (because it was removed from the market in 2005), although other types of flame-retardants are likely to be present.[79] Fiber or felt pads placed under carpeting do not contain chemical flame-retardants.[80]

- Few studies have measured flame-retardant residues in carpet, but carpet installers have PBDE body burdens an order of magnitude higher than that of the general public.[81] In addition, large differences

Infant products containing foam include nursing pillows, strollers, high chairs, and baby carriers. A 2011 study found that 80 percent of the 101 baby products with foam tested contained a flame-retardant.

between PBDE concentrations measured in two rooms in the same house, possibly attributable to carpet in one room and bare wooden floor in another, have been documented.[82]

Home Insulation

- Foam insulation, used for the last 50 years to make buildings more energy-efficient, is required to pass flammability tests. Manufacturers are not required to include flame-retardants in foam, but often add HBCD and TCPP to pass these tests. Two of the most commonly used flame-retardants in foam plastic insulation, HBCD and TCPP, can migrate from insulation and be inhaled or ingested.[83]

- The need for fire-retardants in home insulation is currently being debated. A recent study found that foam insulations protected by a thermal barrier are already fire-safe and that the use of additional flame-retardants does not provide any additional benefit.[84]

In the early 1970s, the U.S. Consumer Product Safety Commission implemented a cigarette-ignition standard for mattresses, which required that a lit cigarette placed on a mattress extinguish without igniting the mattress.

Mattresses and Bedding

- In the early 1970s, the U.S. Consumer Product Safety Commission implemented a cigarette-ignition standard for mattresses, which required that a lit cigarette placed on a mattress extinguish without igniting the mattress.

- In 2007, the commission required mattresses to meet performance standards to withstand fires ignited by other flame sources (including matches, candles, and lighters) and allowed manufacturers to choose to use fire resistant barriers, boric acid-treated fibers, or fire-retardant chemicals to comply with the standard.[85]

- Many U.S. mattress manufacturers claim they use a barrier to comply with current standards instead of chemicals. However, a statement by Great Lakes Chemical Corporation notes that Firemaster 550 can be used in foams found in "padding commonly used on beds" and a statement by IKEA indicates it stopped using PBDEs

in its mattresses in 2000, replaced them with chlorinated Tris (TDCPP) until 2010, and currently uses OP flame-retardants in North America to meet U.S. open flame test requirements.[86]

- Few studies have tested mattresses for flame-retardants in the United States, although researchers in New Zealand correlated concentrations of OP flame-retardants in dust from mattresses with concentrations on floors.[87]

- A study in Sweden found significant correlations between concentrations of some PBDEs and HBCD in air and/or dust and polyurethane foam mattresses.[88]

- Smaller mattresses that contain polyurethane foam may contain flame-retardants instead of the barriers used in adult mattresses. Recent tests detected TDCPP, components of Firemaster 550, and PBDEs in polyurethane foam used in portable crib mattresses.[89]

- Pillows and mattress pads are not required to meet flame-retardant standards, but those filled with polyurethane foam may contain flame-retardant chemicals. Mean bromine levels are substantially

Few studies have tested mattresses for flame-retardants in the United States.

Vehicle seats made of cloth upholstery had bromine levels that were almost 25 times higher than those made of leather.

PBDE Congeners

Congeners are chemical compounds that are closely related to each other. PBDE congeners in consumer products include DecaBDE, OctaBDE, and PentaBDE. PBDE congener number 209 (BDE-209) is a major component of commercial DecaBDE, widely used as a flame-retardant.

higher in pillows made of polyurethane foam, and individuals who sleep on pillows that have a high bromine concentration have increased blood PBDE levels.[90]

- Significant correlations between concentrations of some PBDEs and HBCD in air and/or dust and synthetic bed pillows have been found.[91] At least one study detected TDCPP in mattress pads filled with polyurethane foam.[92]

Vehicles

- Transit vehicles, including autos, buses, and trucks, must meet fire safety standards set by the National Highway Traffic Safety Administration (NHTSA). The use of flame-retardants has become extensive due to the rising percentage of vehicles composed of plastics and electronic devices, and the presence of flammable fuels.

- The most stringent fire safety requirements are set by the U.S. Federal Aviation Administration (FAA) and apply to commercial aircraft. The aircraft industry has relied increasingly on plastic materials that are lighter in weight and more energy-efficient, but potentially flammable. Most large modern aircraft contain nearly 60 miles of electrical cable, and the sheathing of each wire often contains several different flame-retardants.

- Standards for trains are similar to those for buses. The flame-retardant use standards adopted by the National Fire Protection Association (NFPA 130) apply especially to plastic components, foams, textile fabrics and rugs, and electrical cables.

- Concentrations of PBDE congeners in cars have been found at levels higher than those typically found in homes. In a study of PBDE concentrations inside cars, BDE-209 (a DecaBDE congener) was detected at the highest level (97 percent), which represented half the total concentration of flame-retardant.[93]

- Levels of bromine in vehicle seat cushions have been associated significantly with PBDE levels measured in the blood. Vehicle seats made of cloth upholstery had bromine levels that were almost 25 times higher than those made of leather.[94] High concentrations of TCPP have also been found inside automobiles, buses, and subway cars.[95]

Schools

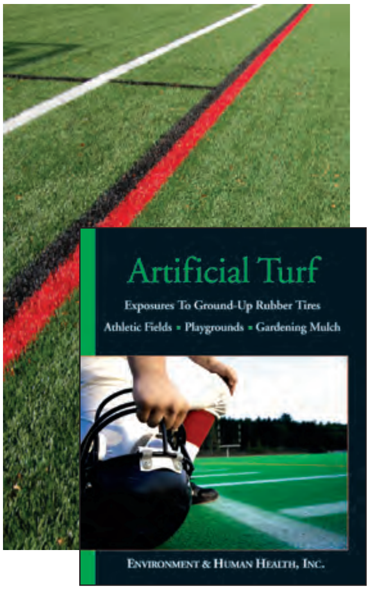
- Concentrations of fire-retardant chemicals inside schools in the United States have not been measured, but concentrations of HBCDs in floor dust from U.K. child daycare centers and primary school classrooms significantly exceeded those reported previously for U.K. houses and offices.

- Young U.K. children's exposure via classroom dust was shown to exceed that of U.K. adults via office dust for all contaminants monitored. A high-end estimate of HBCD dust exposure exceeded U.K. dietary exposure substantially.[96] No similar study has been conducted in the United States.

- A growing number of public and private schools are choosing to install artificial turf fields. The synthetic rubber used in artificial turf is highly flammable, and a variety of flame-retardants are used to comply with flammability standards.[97] The formula used to create the flame-retardant is considered proprietary, and little information is available on the artificial grass fibers or synthetic rubber granules used in artificial turf.[98]

Workplace

- Brominated and OP flame-retardants have been detected in air samples from several work environments, including an electronics recycling plant, a printed circuit boards factory, a computer repair facility, and offices containing computer equipment. The highest concentrations have been detected at a recycling plant at levels that may pose a potential health hazard to the exposed workers.[99]



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Workers in close contact with PBDE-containing electronic equipment, foam recyclers, and carpet layers have higher PBDE concentrations in their blood.

- Exposure to dust at work may result in the greatest exposure to PBDEs for some office workers, aircraft crews, car sale employees, and disposal/recycling of electronic waste workers.[100 101] Workers in close contact with PBDE-containing electronic equipment, foam recyclers, and carpet layers have higher PBDE concentrations in their blood.[102] Exposure to PBDE in the office environment has been linked to PBDE body burden, with exposure likely linked to PBDE residues on hands.[103]

- The office environment is also a predictor of metabolized TDCPP in urine, with significantly lower concentrations of the chemical among workers in new office buildings than in older buildings.[104]

- TBBPA levels in plasma have been found in different occupational groups, including laboratory personnel, circuit board producers, computer technicians, smelter workers, and electronics dismantlers, with highest concentrations found in the latter group.[105]

PBDEs in Swedish Workers' Blood

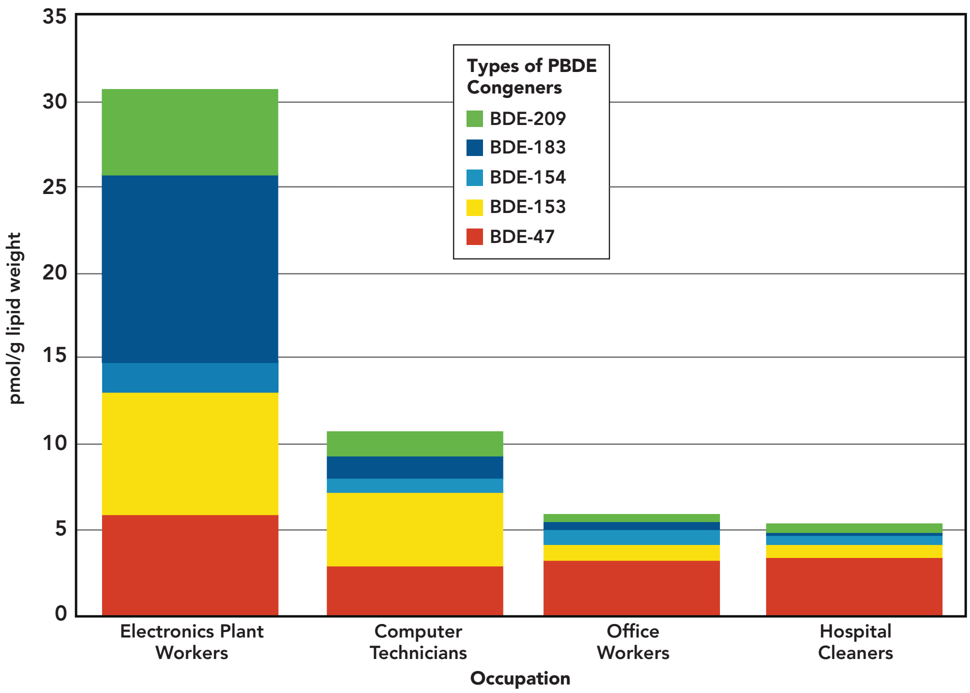


FIGURE 3
Source: *NRDC, http://www.nrdc.org/breastmilk/pbde.asp.*

Children's and Baby Products

Sleepwear

- In 1971, children's sleepwear became the first consumer product to be regulated for flammability standards. Sleepwear was required to be exposed to an open flame for three seconds before self-extinguishing. Using chemical flame-retardants to meet test requirements became common practice in the 1970s, specifically the use of brominated Tris (TDBPP).

- The CPSC banned the use of Tris (TDBPP) in children's pajamas in 1977, due to concerns about its mutagenicity and carcinogenicity. At the same time, they did not specify the type of flame-retardant chemicals that could be used in children's products and did not require their labeling.

- Most synthetic fibers, including most polyester fabrics, has a flame-retardant bonded into them. Cotton pajamas that are tight fitting are not required to contain flame-retardants, and are labeled "must be snug fitting" or "not flame-resistant."

- Sleepwear for children under 9 months is not subject to flammability requirements because they have limited mobility and have a lower risk of catching fire. Sleepwear for children between 9 months and 14 years must meet flammability requirements.[106]

Baby Products

- Chlorinated Tris (TDCPP) is used in baby products that contain polyurethane foam (PUF).[107] Although banned in children's sleepwear, Tris can still be used in car seats, changing table pads, nap mats, crib mattress pads, infant sleepers, and other foam products for infants and young children.[108] In addition, other organophosphate (OP) flame-retardants, including TCEP and TCPP, have been detected in children's products.[109]

Although banned in children's sleepwear, Tris can still be used in car seats, changing table pads, nap mats, crib mattress pads, infant sleepers, and other foam products for infants and young children.

The Chinese Academy of Sciences found widespread use of BFRs, including PBDEs (Penta-, Octa-, and Deca-), in Chinese-made toys. About 80 percent of all toys sold in the United States are made in China.

Car Seats

- Car seats for infants and toddlers are subject to a flame test in accordance with the Federal Motor Vehicle Safety Standard.[110] Car seat materials are exposed to a 15-second open flame test.

- The Ecology Center found brominated flame-retardants in 44 percent of 150 car seats sampled in 2011. They did not test for chlorinated flame-retardants.[111]

Toys

- Toys containing polyurethane foam may contain flame-retardants, depending on when and where they were manufactured. Older toys may contain PBDEs or TCEP; newer ones may contain TCPP and TCDP, which replaced TCEP in polyurethane foam because of health concerns.

- The Chinese Academy of Sciences found widespread use of BFRs, including PBDEs (Penta-, Octa-, and Deca-), in Chinese-made toys.[112] About 80 percent of all toys sold in the United States are made in China.[113] Some flame-retardants are very soluble and can be released by sucking on toys.[114]

Food

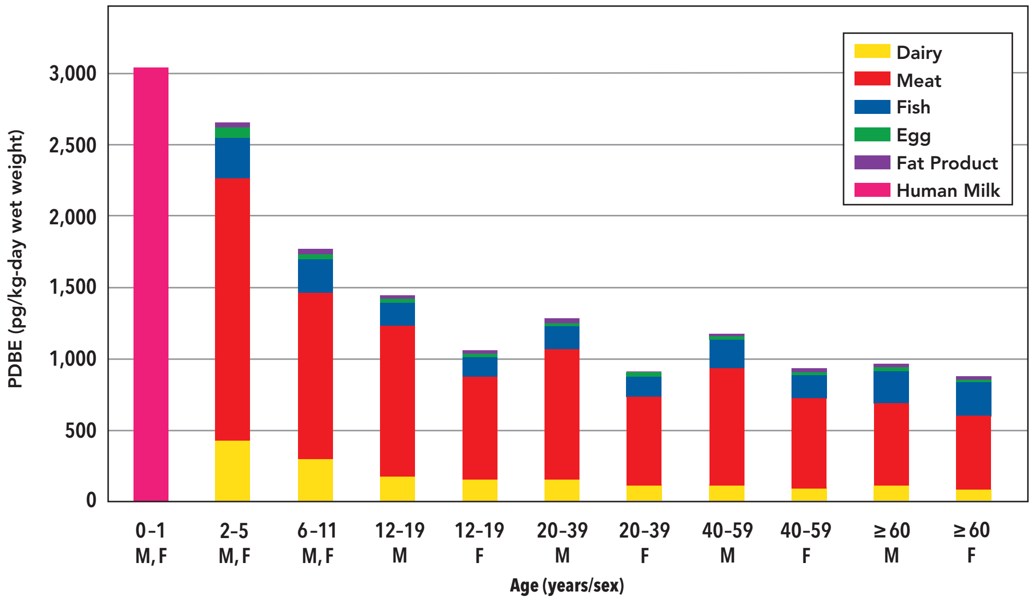
- The extent of food and water contamination by chemical flame-retardants is not well studied, and without government regulations, it not clear what levels of flame-retardants in food should be considered harmful. Most studies conducted on flame-retardants in food have measured PBDEs.

- Dietary exposure to PBDEs may be higher than estimated indoor dust and water ingestion exposure, possibly from food processing and packaging contaminating the food supply. In one market basket survey, meat, dairy, and egg consumption accounted for nearly 90 percent of PBDE dietary exposure.[115]

- Significant associations between PBDE body burdens and poultry and red meat consumption have been identified in National Health and Nutrition Examination Survey participants.[116]

- HBCD has been detected in foods that are high in fat, including fish and deli meat, and at relatively high levels in peanut butter.[117] The source of food contamination is unknown, although HBCD in soil can transfer into vegetables.[118]

Dietary Intake Estimates of PBDEs in U.S. and Canada



Daily PBDE dietary intake of U.S. population by age and food group in picograms (pg)/kg body weight); M (male); F (female)

TABLE 4
Source: *Schecter A, et al. Polybrominated diphenyl ether (PBDE) levels in an expanded market basket survey of U.S. food and estimated PBDE dietary intake by age and sex. Environ Health Perspect 2006;114:1515-1520.*

- Dietary exposure of vegetarians to HBCDs is lower than that for people consuming a mixed diet.[119] Fish and meat are considered the major sources of HBCD exposure in the United States, Europe, and China.[120]

- Few studies have measured flame-retardants migrating from food packaging or bottled beverages, and it is nearly impossible to identify the chemicals in the plastics used to package food. PBDEs have

Few studies have measured flame-retardants migrating from food packaging or bottled beverages, and it is nearly impossible to identify the chemicals in the plastics used to package food.

been detected in butter, possibly from packaging contaminated from electronics. Food packaging is also suspected as the source of elevated levels of the congener BDE-209 in cream cheese.[121]

Drinking Water

- The federal Safe Drinking Water Act (SDWA) does not regulate flame-retardants in water. Several studies indicate that chlorinated flame-retardants may be present at low levels in public and private drinking water from wastewater discharges.
- Brominated flame-retardants may be in bottled water because they migrate from plastic containers. More studies are needed to confirm the extent of contamination.
- Chlorinated flame-retardants have been widely detected in ground water and surface water sources that could be used for drinking.

Food Packaging That May Leach PDBEs

Food Packaging	Food Packaging Material	Typical Uses
Plastic foil	PET	Yogurt cup lid
	HDPE	Milk, dairy products
Plastic bottle	PET	Soft drinks
	Polycarbonate	Repeated use water bottles, baby feeding bottles
	Polystyrene	Yogurt, dairy products, honey, syrup and ice cream, jam and marmalade tubs and containers; trays for pre-packaged meat and fruit; vending cups

TABLE 5
Source: *Wagner C. Plastic. Common contaminants of plastic food packaging materials. Food Packaging Forum News 9 October 2012.*

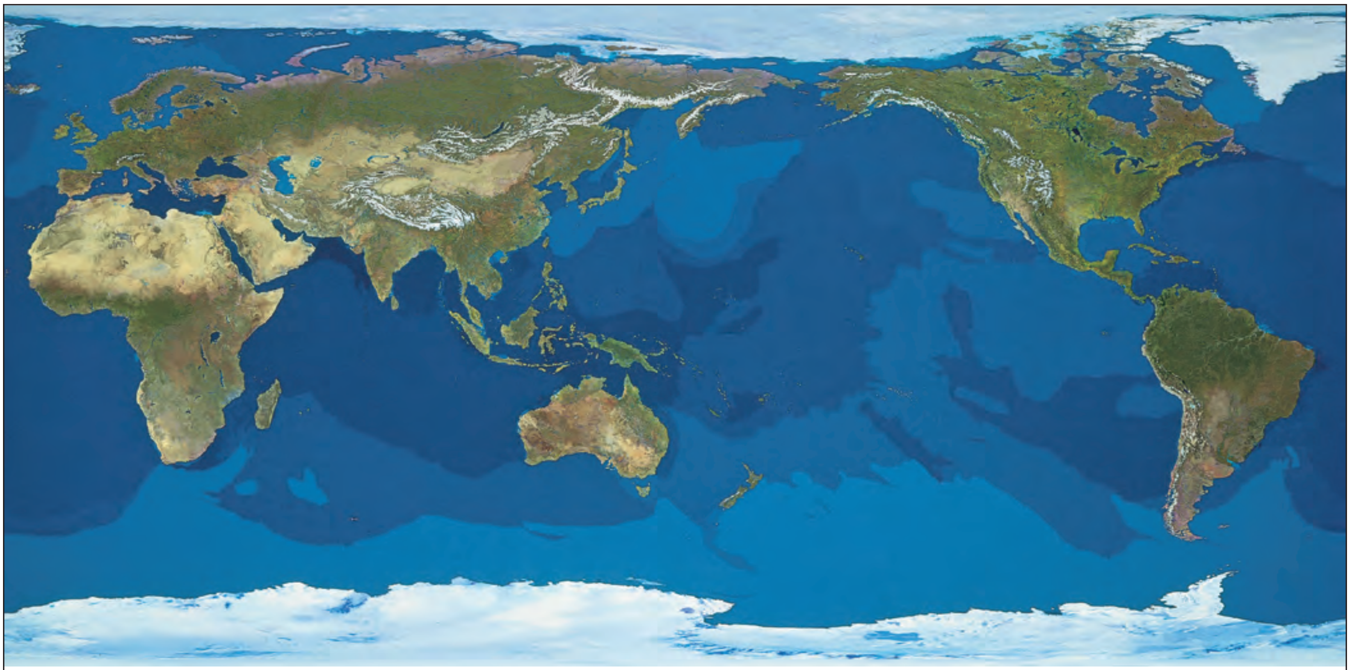
- Several chlorinated flame-retardants, including TCEP, TCPP and TDCPP, are found in most treated wastewater samples because they are removed poorly during wastewater treatment.[122]

- Little information is available on chemicals in private well water, but a 2011 study on Cape Cod found that septic systems located in sandy soils might be a source of flame-retardants in well water.[123]

- Brominated flame-retardants are not as prevalent in the aquatic environment as chlorinated flame-retardants, but they may be present in bottled water due to leaching from plastics. Organo-brominated compounds are used in making PET and PC plastics, yet little is known about their ability to migrate into bottled water or other beverages.

- PBDE congeners have been reported in high-density polyethylene (HDPE), polystyrene, polypropylene, and PET. BDE 209 was detected in three out of four bottled water samples in a small study.[124]

The federal Safe Drinking Water Act (SDWA) does not regulate flame-retardants in water.



Both brominated and chlorinated flame-retardants have been detected in the Arctic and the Antarctic, indicating their potential to travel great distances.

Globally Dispersed Residues

- Flame-retardants, now ubiquitous in our environment, are detected in air, sediment, plants, and animals. They are found in fish, sea birds, marine mammals, and in wildlife from the North Pole to the Mediterranean Sea.[125]

- Both brominated and chlorinated flame-retardants have been detected in the Arctic and the Antarctic, indicating their potential to travel great distances.[126]

- Studies indicate air and ocean currents from western Europe and eastern North America are important sources of these contaminants. Concentrations of flame-retardants are generally highest in marine top predators, including killer whale populations in Alaska and gulls from the Barents Sea, with the highest concentrations near populated areas.[127]

- PBDEs are the most widely studied flame-retardants. Concentrations in some media exceed PCB levels. High concentrations of some PBDE isomers may be sufficient to cause adverse effects in some wildlife.[128]

- There are few data available for OP flame-retardants in air or soil, and they have received little attention with respect to their prevalence in wildlife. However, global occurrence is evidenced by the recent discovery of several OP flame-retardants in airborne particles over the Northern Pacific, the Indian Ocean toward the Polar Regions, and in the Antarctic ice sheet.[129]

- Millions of tons of flame-retardants are produced every year, consisting of hundreds of different types of compounds with a large range of physical and chemical properties.

- Accurate detection and monitoring methods to assess levels of these compounds in the environment are critical to understanding their effects on the environment and human health.[130]

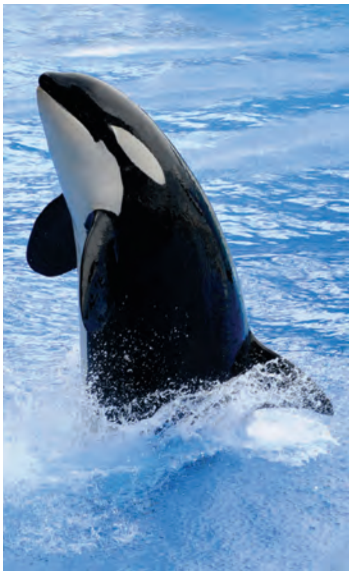
Air

- Outdoor air measurements taken in several U.S. states indicate that levels of flame-retardants in outdoor air are higher in the United States than in Europe.[131]

- Concentrations in the air tend to be higher in urban settings, where they are released from commercial products.[132] Evidence exists for long-range atmospheric transport of PBDEs and other BFRs.[133]

Soils

- Flame-retardants enter air during their manufacture and use in consumer products and eventually settle to soil. Most flame-retardants adhere to soil, which may reduce human exposure; however, plants increase the exposure risk by taking up flame-retardants and enhancing their bioavailability.[134]



Concentrations of flame-retardants are generally highest in marine top predators, including killer whale populations in Alaska and gulls from the Barents Sea, with the highest concentrations near populated areas.

Chlorinated flame retardants are more frequently detected in wastewater than are brominated flame-retardants. They are widely detected in streams, drinking water and ground water in many parts of the world.

- Several flame-retardants, including PBDEs, HBCD and TBBPA, have been detected in sewage sludge. Applied to agricultural fields, sludge is one pathway for soil contamination.[135]
- Soil in developing Asian countries is contaminated with flame-retardants, including PBDEs and HBCD, from disposal of plastics and electronic wastes.
- Soil samples collected from open waste dumping sites in Cambodia, India, Indonesia, Malaysia, and Vietnam show that PBDEs are the dominant contaminants in the dumping sites in developing Asian countries.[136]
- No regulations or management policies for PBDEs currently exist in China. Few data are available for sediment and soil levels of organophosphate (OP) flame-retardants in the United States.

Water

- In three limited exposure assessment studies, EPA found PBDEs in surface water. No data are available for ground water or drinking water.[137]
- Chlorinated flame-retardants are more frequently detected in wastewater than are brominated flame-retardants.[138] They are widely detected in streams, drinking water and groundwater in many parts of the world.
- The persistent behavior of the Tris flame-retardants (TCEP, TCPP and TDCPP) has resulted in their occurrence in most treated wastewater samples and in surface water from discharge of municipal and industrial wastewater.[139] These Tris flame-retardants are not biodegradable during wastewater treatment, and conventional drinking water treatments are ineffective in removing chlorinated flame-retardants.[140]

- Numerous studies have detected TCEP at low levels in ground water, drinking water, and surface water throughout the developed world since the 1970s.[141] It was detected in drinking water in the U.K. in 1976, and in Canadian treatment plants and drinking water a few years later.[142]

- In the early 1980s, TCEP was detected in the Great Lakes municipalities and in groundwater near Boston.[143] By the mid 1980s, Japanese studies had documented its presence in river and sea samples and in drinking water.[144]

- While not detected with similar frequency in ground and drinking water, another OP flame-retardant, TCPP, has shown up in remote volcanic lakes. The significance of this is the ability of flame-retardants to be transferred great distances.[145]

- While levels of OPs detected in water are generally low, the widespread nature of the contamination and the numerous exposure pathways cause an increase in flame-retardant uptakes. OPs' exposure pathways include breast milk, fish ingestion, inhalation of dust, and intake of food and water.

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PBDE body burdens in the U.S. are linked to the consumption of red meat and poultry, but it is not clear how the meat and poultry become contaminated.

Livestock

- PBDE body burdens in the U.S. are linked to the consumption of red meat and poultry, but it is not clear how the meat and poultry become contaminated. PBDEs measured in 2008 showed that beef samples had the lowest PBDE levels, followed by hogs, chickens and then by turkeys.[146]

- PBDE concentrations in U.S. meat and poultry have decreased by 60 percent. This is perhaps due to the fact that PBDEs stopped being manufactured in 2004. PBDE levels in U.S. meat and poultry have declined since manufacturing ceased; however, exposure pathways of PBDEs to livestock are still not known.[147]

Fish

- The first reports of PBDEs in fish were documented in fish from Swedish rivers in 1981, but intensive studies on their occurrence in fish started a decade later. Flame-retardant chemicals have since been found in fish samples collected around the world in industrialized and developing countries.[148]

- Concentrations of flame-retardants in fish are highly variable, probably because of the proximity of the fish feeding grounds to sources of flame-retardant chemicals. Fish caught in Europe have about 10 times lower PBDE concentrations than fish caught in North America.[149]

- PBDEs, mostly BDE-47 (a major constituent of PentaBDE) were found at relatively high levels in freshwater fish from an area in Virginia that has historically been a center for furniture and textile manufacturing.[150]

TABLE 6
***Source:** JECFA (Joint FAO/WHO Expert Committee on Food Additives) Bend J, Bolger M, Knapp AG, Kuznesof PM, Larsen JC, et al. Evaluation of certain food additives and contaminants. World Health Organ Tech Rep Ser. 2007;947:1–255.*

Daily Dietary PBDE Intake

Food	PDBE Levels
Meat and poultry	66 ng/day
Fats and oils	47 ng/day
Fish and shellfish	40 ng/day
Other	29 ng/day
Dairy	24 ng/day
Eggs	8 ng/day

U.S. Daily PBDE dietary intake in nanograms (ng)

- Farm-raised Atlantic salmon contains higher levels of PBDEs than wild Pacific salmon, possibly from exposure to contaminants closer to shore. PBDEs are also higher in bluefish and rockfish that migrate along U.S. industrialized coasts.[151] In addition to the local sources of flame-retardants that contaminate fish, atmospheric deposition in faraway lakes is also a source of contamination.

- PBDE concentrations in fish from western U.S. National Parks and preserves are higher than levels found in other mountain fish and in Pacific Ocean salmon, an indication that atmospherically deposited PBDE can accumulate in fish at high elevations, reaching concentrations relevant to human and wildlife health.[152]

- Levels of PBDE detected in fish from Czech rivers are similar to levels detected in Canada, Sweden, and Spain. Concentrations of HBCD in Czech fish samples are the of same order of magnitude as the most abundant PBDE detected, PBDE-47.[153]

- Concentrations of HBCDs in mussels from Asia to Brazil, in tilapia from Ghana, and in fresh water fish from Czech rivers indicate global environmental pollution by HBCDs.[154]

- In China, PBDEs have been detected in commonly consumed seafood (fish, bivalves, shrimp, crab, and cephalopods) at levels that may pose some health risks.[155]

- In Norway, an association was detected between HBCD serum concentrations in Norwegians and their consumption of contaminated fish.[156]

- The health effects of PBDEs on fish are not well understood. But Chinook salmon fed a diet of five PBDE congeners at environmentally relevant levels were more susceptible to infectious diseases.[157]

In China, PBDEs have been detected in commonly consumed seafood (fish, bivalves, shrimp, crab, and cephalopods) at levels that may pose some health risks.

Flame-retardants are present in both coastal and deep-sea marine mammals. These pollutants concentrate in marine mammals due to their long lives, inability to break down organic pollutants, and their high position in the marine food chain.

Marine Mammals

- Flame-retardants are present in both coastal and deep-sea marine mammals. These pollutants concentrate in marine mammals due to their long lives, inability to break down organic pollutants, and their high position in the marine food chain.

- Concentrations of PBDEs in dolphins and sharks are one to two orders of magnitude greater than those in lower trophic-level fish species, a sign of biomagnification in the marine food chain.[158]

- Levels of HBCD and PBDEs are seen in marine mammals, especially in their fatty tissues and breast milk.[159] Levels of PBDEs in the diet of non-migrating harbor seals from sites in Washington State, British Columbia, and Florida have become a concern.

- Off the coast of Florida, an exponential increase in the concentrations of PBDEs in both sharks and dolphins has been measured, with a doubling time estimated at two to three years for bull sharks and three to four years for bottlenose dolphins.[160]

- The detection of PBDEs in open sea marine mammals feeding in deep offshore waters indicates that PBDEs are also in deep-water oceanic food webs.[161]

- Japanese deep-sea sharks have some of the highest levels of PBDEs in their oil. These sharks are sought after for their relatively large livers that contain oil promoted as a dietary supplement.[162]

Wildlife

- More data are available for PBDEs in wildlife than for other flame-retardant compounds, and data indicate that PBDEs are widely distributed in wildlife from Europe, Australia, North America and the Arctic. Concentrations seen in Arctic biota reflect the impact of long-range atmospheric transport.[163]

- PBDE levels in British Columbian grizzly bears feeding on salmon from the north Pacific Ocean show higher levels of the heavier PBDE, BDE-47, than those seen in grizzly bears feeding on terrestrial vegetation, which carry higher levels of the bioaccumulative BDE-209.[164]

- Elevated PBDE burdens are seen in North American aquatic birds, compared to those from the rest of the world. North American and Chinese terrestrial birds show some of the highest BDE-209 concentrations yet reported in wildlife, an indication that urban environments in general, and electronic recycling in particular, may increase exposure to DecaBDE.[165]

- There are very few studies of OP flame-retardants in wildlife. However, common OP flame-retardants (TDCPP and TCPP) have been detected in wild birds, various fish species, and herring gull eggs in the Great Lakes region.[166]

Elevated PBDE burdens are seen in North American aquatic birds, compared to those from the rest of the world.

V. Health Concerns Overview

Endocrine-disrupting chemicals can mimic estrogens (female sex hormones), androgens (male sex hormones), and thyroid hormones, which can contribute to hormonally induced cancers, including breast cancer.

Endocrine Disruption

- Endocrine-disrupting chemicals (EDCs) can mimic estrogens (female sex hormones), androgens (male sex hormones), and thyroid hormones, which can contribute to hormonally induced cancers, including breast cancer. They can also adversely affect normal development, reproduction and neurologic function.[167]

- Recent human studies demonstrate a decline in semen quality and male testosterone levels. Studies have shown an increase in rates of developmental anomalies of the reproductive tract, testicular cancer, thyroid cancer, congenital hypothyroidism, and neurologic development disorders.[168]

- Studies in animals were the first to suggest that flame-retardants could affect the endocrine system. Altered male hormones and reduced sperm counts were found in animals exposed to PBDEs, as well as malfunctions of the thyroid hormone system.[169]

- Studies in humans have been even more alarming. PBDE levels in maternal and cord blood tissues have been associated with the absence of one or both testes in male infants, lower birth weights, and neurodevelopmental and behavior problems in children, raising concerns about exposure of women to PBDEs during pregnancy.[170]
- Concerns that PBDEs disrupt the endocrine system led the National Institute of Environmental Health Sciences (NIEHS) to fund studies on their health effects in people.
- A study of a predominantly Mexican immigrant population was the first to report that higher PBDE concentrations in women's blood were associated with a longer time trying to get pregnant.[171]
- A more recent NIEHS-funded study implicated Firemaster 550 as an endocrine disruptor and obesogen at environmentally relevant levels.[172]
- The NIEHS is currently continuing a multigenerational endocrine disruption study using the Michigan PBB cohort, with a focus on the offspring of those exposed who show evidence of endocrine disruption.[173]
- Sons of highly exposed women experienced an increased risk of genitourinary conditions and slower growth and pubertal development, and highly exposed girls had an earlier age at menarche and an increased risk of miscarriages.[174]
- PBDEs and TBBPA have chemical structures similar to thyroid hormones that are essential for fetal development. TBBPA exhibits

PBDE levels in maternal and cord blood tissues have been associated with the absence of one or both testes in male infants, lower birth weights, and neurodevelopmental and behavior problems in children, raising concerns about exposure of women to PBDEs during pregnancy.

Most of the flame-retardants in use today have not been tested for their potential to cause cancer.

thyroid hormone activity in laboratory studies and has estrogenic activity in experimental animals.

- TBBPA-exposed animals had decreased thyroid hormones and increased weight of testes and pituitary in male offspring.[175] One metabolite produced by TBBPA is BPA, a known estrogen mimic.[176] Newer studies suggest that HBCD and Firemaster 550 also have the potential to disrupt the endocrine system.[177]

- Organophosphate (OP) flame-retardants have been poorly studied; however, there is evidence suggesting adverse endocrine and reproductive effects.[178]

- At a U.S. infertility clinic, a small study suggested that exposure to TDCPP and TPP from house dust could be associated with altered hormone levels and decreased semen quality in men.[179]

- Several animal studies on OP flame-retardants show reproductive health effects, raising concerns about unknown human health effects associated with exposure to these chemicals.[180]

Cancer

- Most of the flame-retardants in use today have not been tested for their potential to cause cancer. Two structurally similar flame-retardants, TCEP and TDBPP, have been identified as causing cancer under California's Proposition 65, and are listed as known to cause cancer. TCEP has been detected in indoor air samples and in dust in homes, offices, schools, and cars.[181]

- TDCPP is also a probable human carcinogen, based on sufficient evidence in animals. These chemicals have been detected in dust indoors, where they migrate to the surface and are released from consumer products.

- In the only study available on TDBPP in house dust, it was detected in 75 percent of homes tested.[182] TDCPP was detected in 96 percent of house dust samples collected in the Boston area.[183]

- EPA considers DecaBDE to have "suggestive evidence of carcinogenic potential" based on animal studies.[184]

Brain Function

- Organohalogen compounds such as DecaBDE, TBBPA, and HBCD are known to have neurotoxic effects on the developing brain. In pregnant women, these compounds cross the placenta to the fetus. During critical periods of fetal growth and development, organohalogen compounds may interfere with developmental processes in the brain.[185]

- The chemical structures of organophosphate (OP) flame-retardants are similar to those of OP insecticides, which were designed to be

Organohalogen compounds such as DecaBDE, TBBPA, and HBCD are known to have neurotoxic effects on the developing brain.

The most recent and largest study on childhood exposure to PBDEs showed an association between prenatal and childhood exposures and deficits in attention, fine motor coordination, and cognition in school-aged children.

neurotoxic to insects, and many are capable of inhibiting critical enzymes in humans necessary for neurological growth and function.

- Organophosphate (OP) flame-retardants (TCEP, TCPP, and TDBPP) are toxic via several different biochemical pathways, increasing the concern for neurotoxicity.[186]

- Over the last decade, animal and laboratory studies suggest that brominated flame-retardants (BFRs) are potentially neurotoxic.[187] In 2009, the first study assessed their neurodevelopmental toxicity in humans, demonstrating that developmental deficits in young children were associated with prenatal exposures.[188]

- Several small studies have subsequently associated concentrations of several PBDE congeners in umbilical cord blood of newborns with neurodevelopmental effects in early childhood.[189]

- The most recent and largest study on childhood exposure to PBDEs showed an association between prenatal and childhood exposures and deficits in attention, fine motor coordination, and cognition in school-aged children.[190]

- A large California study investigated the neurobehavioral effects of brominated flame-retardants in humans and found an association between low-level PBDE exposure and changes in motor function and serum levels of thyroid hormones.[191]

- Findings from a 2013 NIEHS-funded study have also identified PBDEs as a possible risk factor for Parkinson's disease and neurodegenerative diseases. The authors of the study note the importance of additional research on PBDEs as a potential risk factor for Parkinson's disease and other neurological disorders.[192]

Potential Health Risks of Common Flame-Retardants

TABLE 7

	Reproductive	Endocrine Disruption	Brain Function	Cancer	Developmental
PentaBDE	●	●	●		●
OctaBDE		●	●		●
DecaBDE	●	●	●	●	●
TBBPA		●	●		
HBCD	●	●	●		●
FM 550	NS	●	NS	NS	NS
TDBPP	NS			●	NS
TDCPP	NS	●	●	●	NS
TCPP	NS			NS	NS
TCEP	●		●	●	NS
TCP	●		●	NS	NS
TBEP	NS		●	NS	NS

NS = Not studied

Susceptiblity of Children, Infants and Fetuses

Exposure to flame-retardant chemicals is a special concern for children because of their relatively higher exposure on a body weight basis compared to adults.

- Children's exposure to chemical flame-retardants is now obvious, and their tissue concentrations are normally higher than those found in adults. Exposure to flame-retardant chemicals is a special concern for children because of their relatively higher exposure on a body weight basis compared to adults.

- Levels of PBDEs causing developmental neurotoxicity in animals are similar to levels found in highly exposed infants and toddlers.[193] Significant associations between serum PBDEs in humans, and altered thyroid hormone levels with motor, cognitive, and behavioral performance measurements in children, raise special concerns for children, who face a lifetime of exposure.[194]

- Toddlers have been found to be exposed to PDBEs via house dust and their frequent hand-to-mouth movements.[195]

- House dust may account for 80 percent of total daily PBDE exposure for toddlers, compared with 14 percent for adults.[196] Ingestion of indoor dust can lead to as much as a 100-fold higher PBDE exposure for toddlers than adults.[197]

- PBDE concentrations in infants and toddlers in Australia are reported to be four to five times higher than concentrations in adults.[198] Children in one California family were found to have 2- to 15- fold higher levels than their parents, likely from greater exposure to house dust. Levels of BDE-209 in the children were comparable to levels seen occupationally.[199]

- Poorer children may have even greater exposure to flame-retardant chemicals.[200, 201] Latino children living in California have much higher PBDE serum levels than Latino children living in Mexico. High PBDE levels could be due to poorly manufactured or deteriorating furniture that may release more flame-retardant compounds.

- Congeners found in greatest concentration in human serum in the United States are BDEs 47, 99, 100 and 153. These often comprise mixtures used as flame-retardants.[202]

Latino children living in California have much higher PBDE serum levels than Latino children living in Mexico.

PBDEs in Children's Blood: California and Mexico

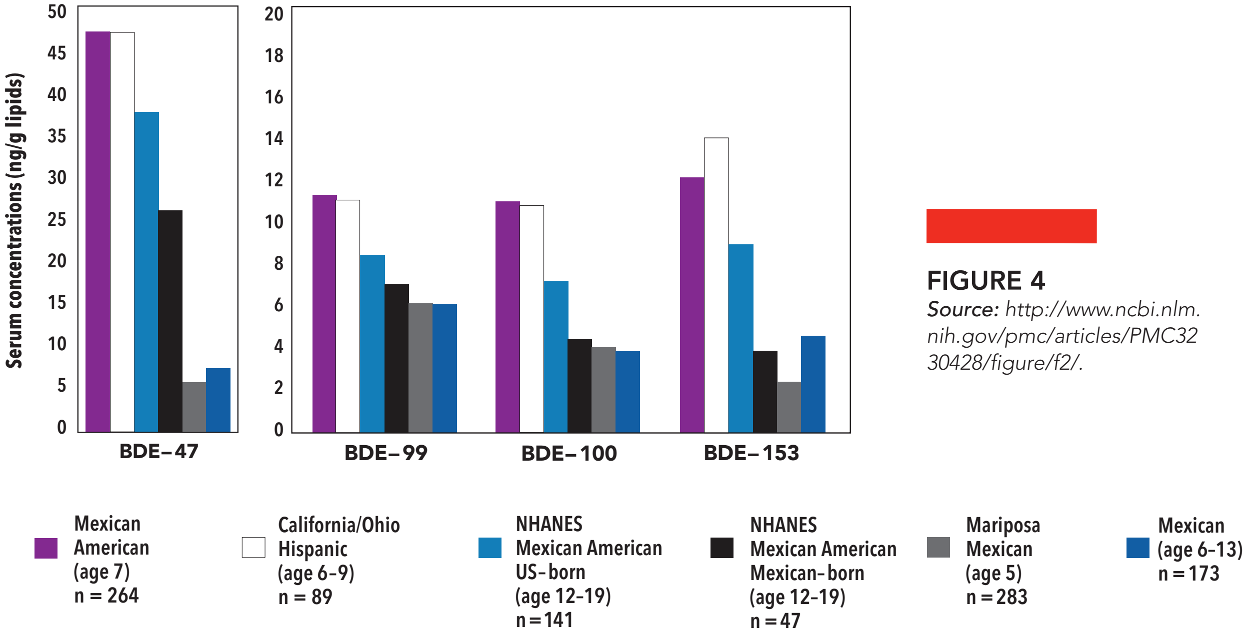

FIGURE 4
Source: *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230428/figure/f2/.*

Concentrations of PBDE congeners in Mexican-American children and Mexican children, compared with concentrations from other cohorts of Latino children.

- For infants, the greatest source of PBDE exposure occurs *in utero* and from breastfeeding.[203] The high lipid concentration in milk enhances exposure for the nursing infant, and several studies show that infant consumption of human milk is the largest contributor to lifetime exposure.[204] There is a positive association between PBDE levels in household dust and levels in breast milk.[205]

- Data from Sweden, the only nation with a comprehensive breast milk monitoring program, show that PBDE levels in breast milk have increased exponentially since the 1970s, doubling every five years from 1972 to 1996, prior to its phaseout.[206]

- Data from the Netherlands show that HBCD levels have increased since it was commercially introduced as a flame-retardant in the

There is a positive association between PBDE levels in household dust and levels in breast milk.

PBDEs in Breast Milk and Fat Samples Worldwide

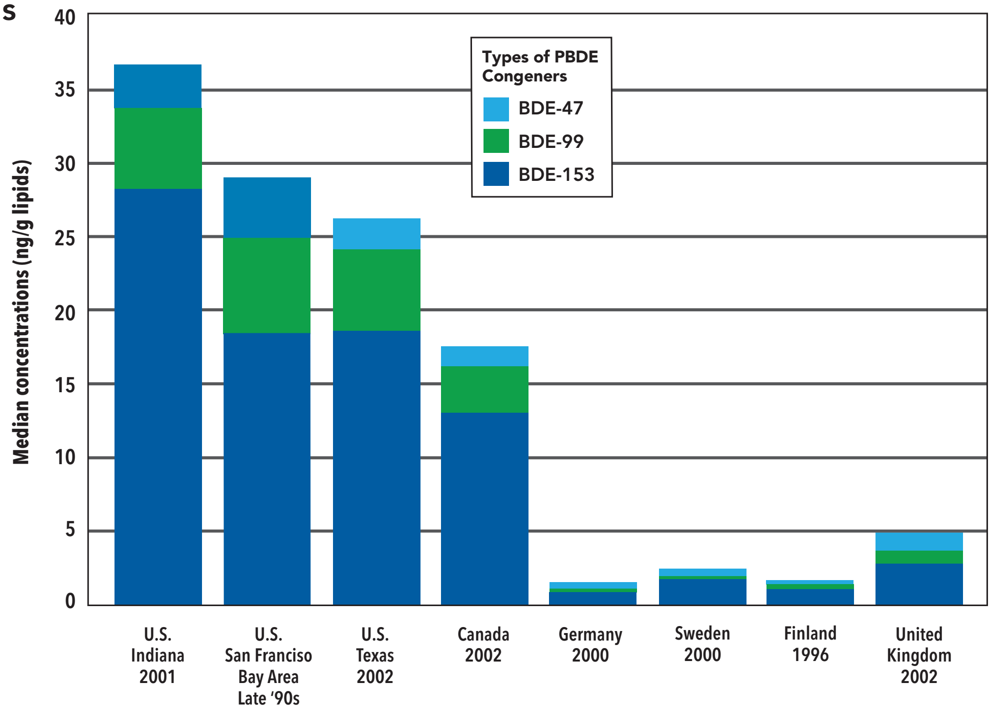

FIGURE 5
Source: NRDC, *http://www.nrdc.org/breastmilk/pbde.asp. Shecter et al., 2003; Mazdai et al, Environ Health Perspective, July 2003; Kalantzi et al., EHP, July 2004.*

1980s.[207] PBDEs in human breast milk in North America are higher than those reported in Europe, Asia, or Australia.[208]

- While the effects of infant consumption of breast milk is not clear, several small studies raise concerns that there may be an association between increasing PBDE concentrations in breast milk and health effects.

- Cognitive development effects in the first year of life have been associated with exposure to higher BDE-209 concentrations.[209] And a "small, imprecise, yet consistent" positive association was found between BDEs 47, 99, and 100 and activity/impulsivity behaviors in another study.[210]

Endocrine disrupting effects have been correlated with PBDE exposure in girls, pregnant women, and men.

Studies of Human Populations

- A few small epidemiological studies show associations between prenatal exposure to PBDEs and neurodevelopmental impacts in children, based on PBDE levels in cord blood or maternal serum.[211]

- Two other studies suggest an association between PBDE concentrations in breast milk and impaired infant cognitive development, particularly for BDE-209.[212] These studies require confirmation in larger studies.

- Endocrine disrupting effects have been correlated with PBDE exposure in girls, pregnant women, and men.[213] Data on human health risk from exposures to OP flame-retardants are lacking.

- Only one human study on OP flame-retardants has been conducted to date. It found a relationship between TDCPP and TPP in house dust with hormone levels and semen quality in men.[214] No studies specifically address exposure to OP flame-retardants in children.

TABLE 8
Sources: See footnote numbers at far right, 215–224, for citations in the endnotes on page 103.

PBDE Epidemiologic Studies

Population	Health Outcomes	Author
Neurodevelopmental Effects		
California Birth Cohort	Prenatal and childhood exposures associated with poorer attention, fine motor coordination, and cognition.	Eskenazi et al., 2013[215]
Belgium Adolescents	PBDE exposure associated with changes in motor function and serum levels of the thyroid hormones.	Kiciński et al., 2012[216]
Spain Mother-Child Pairs	Association between PBDE concentrations in colostrum and impaired infant cognitive development, particularly for BDE-209.	Gascon et al., 2012[217]
Spain Birth Cohort	A statistically significant higher risk of poor social competence, a consequence of postnatal PBDE-47 exposure.	Gascon et al., 2011[218]
Breast Milk PBDEs from Southern Taiwan	Prenatal or postnatal exposure to BDE-209 potentially delays neurological development.	Chao et al., 2011[219]
New York City Women	Those with higher concentrations of PBDEs in umbilical cord blood at birth scored lower on tests of mental and physical development between age one and six.	Herbstman et al., 2010[220]
Denmark	Prenatal exposure associated with reduced fine manipulative abilities and increased attention deficits.	Roze et al., 2009[221]
Endocrine Disruption		
U.S. Adolescent Girls (NHANES, 2003-2004)	High concentrations of serum PBDEs during adolescence associated with a younger age of menarche.	Chen et al., 2011[222]
California Pregnant Women (Low-Income, Mexican Immigrant)	Significant decreases in fertility.	Harley et al., 2010[223]
U.S. Infertility Clinic, Men	Altered hormone levels in men were related to PBDE exposures.	Meeker et al., 2009[224]

VI. Law and Regulation

Stockholm Convention on Persistent Organic Pollutants (POPs)

- The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty that bans or severely restricts the production, use, trade, and disposal of highly persistent and hazardous chemicals.

- POPs are chemical substances that persist in the environment and bioaccumulate. They include some persistent pesticides, such as DDT, dieldrin, and chlordane, industrial chemicals such as PCBs, and some by-products of chemicals, such as dioxins and furans. POPs are persistent in the environment, as they resist being broken down by sunlight, chemical and/or biological processes.

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- The POPs treaty was signed in 2001, became legally binding in 2004, and lists 12 chemicals that signatory nations agree to discontinue production and use. The listed chemicals include pesticides, flame-retardant PCBs, and unintentional contaminants, such as dioxins, furans and hexachlorobenzene (HCB).

- Currently, 179 nations and the European Union (EU) are parties to the treaty, and the U.S. has signed the treaty. The U.S. Senate, however, has not ratified the treaty due to inconsistencies between the POPs Treaty requirements and provisions in TSCA and the federal pesticide law, FIFRA. Both TSCA and FIFRA would need amending before ratification would be possible.

- The principal problem with the U.S. pesticide laws is that they permit the export of pesticides that have been banned in the United States, if product recipients receive a one-time notification that the U.S. EPA registrations have been revoked.

- The problem with TSCA is more extensive, since TSCA demands cost-benefit analysis as a decision standard, has numerous exemptions discussed below, and also permits U.S. firms to export hazardous chemicals banned domestically. U.S. ratification of the Stockholm, Rotterdam, and Aarhus conventions remains stalled awaiting Senate approval, for similar reasons of inconsistency with current U.S. statutes.

- Nations that have signed and ratified the Stockholm Convention Treaty added the fire-retardant HBCD to the list of 22 chemicals that governments are working to phase out from production and use. Nations agreed that insulation containing HBCD would be labeled as such until 2019, when HBCD will be phased out.

Federal TSCA Law and Regulation

The TSCA Paradox

- Congress in 1976 passed the Toxic Substance Control Act (TSCA). The statute was intended to control chemical hazards in solvents, fuels, plastic polymers, flame-retardants, metals, and other classes of products that are the building blocks of consumer goods.

- The name Toxic Substance Control Act implies "control," and the purpose implies Congressional intent to protect the environment and human health from significant risks. But a careful reading of the statute demonstrates that legislators denied EPA the legal authority it needed to regulate either the 62,000 commercial toxic substances then in international commerce, or those introduced after the passage of the statute.

- TSCA also does not provide EPA with the needed financial resources or statutory deadlines, and TSCA depends heavily on EPA expertise, rather than requiring manufacturers to produce evidence of the safety of their products.

TSCA's Catch-22

- TSCA requires that commercial chemicals, including flame-retardants, not pose "an unreasonable risk of injury to health or the environment." Knowledge of "unreasonable risk" normally is difficult to obtain, costly, and time-consuming, and will always be debated by the manufacturers.

- To ask the manufacturer for data, EPA must already possess knowledge of significant risk, and this is a clear impossibility. Furthermore, EPA does not have the financial resources to conduct its own studies.

Congress in 1976 passed the Toxic Substance Control Act. The statute was intended to control chemical hazards…. But a careful reading of the statute demonstrates that legislators denied EPA the legal authority it needed.

TSCA gives the impression that it is a statute designed to protect the public from toxic substances while it provides NO significant authority or funding to test nearly 80,000 chemicals now in international commerce.

- The effect is that EPA faces the burden of developing data well after the chemicals have been sold, used, and discarded. TSCA gives the impression that it is a statute designed to protect the public from toxic substances while it provides NO significant authority or funding to test nearly 80,000 chemicals now in international commerce.

TSCA's Exemptions

- When TSCA went into effect, 62,000 chemicals already in commerce were listed but immediately exempted or "grandfathered" from any data submission requirements.

- Since that time, 45,000 additional chemicals have been introduced to commerce, yet nearly half of these were reported to EPA after companies began to sell them. The effect is that among U.S. chemicals produced in highest volumes, 90 percent are exempt from federal review under TSCA.

- Congress also exempted classes of chemicals if they were regulated by other statutes. These include pesticides, pharmaceuticals, tobacco, nuclear materials, food and additives, and munitions.

- TSCA exempts manufacturers from reporting to EPA if they produce less than 10,000 kilograms (22,000 pounds) annually, despite the fact that this volume of many natural and synthetic compounds could easily have lethal effects.

- Many chemicals have a high toxicity even in exceptionally small amounts, meaning that this volume threshold is a poor regulatory tool to control risk.

- Also, polymers that are not "chemically active or bioavailable" escape review, regardless of toxicity. Finally, chemicals that are released to the environment in low volumes, resulting in low exposures (EPA's LOREX Program) are exempted.

Trade Secrecy

- Trade secrecy permits flame-retardant manufacturers to claim that knowledge they possess or develop is "confidential business information," which protects their proprietary data from disclosure to the public or government.[225] This is specifically permitted by TSCA to protect intellectual property and corporate research and development costs.

- Secrecy also inhibits the public's ability to understand where chemicals may reside in their environments and products. The fundamental question is: When should a corporation be allowed to restrict government and public access to knowledge necessary to understand the danger posed by a flame-retardant or other toxic chemical?

No Labeling Requirements

- The labeling of flame-retardant chemicals in consumer products is NOT required by Congress, EPA, FDA, or the Consumer Product Safety Commission. It is therefore impossible for consumers to avoid flame-retardants in their purchases.

Supply Chain Confusion

- The absence of any flame-retardant labeling or warning requirements in federal law also makes it difficult if not impossible for product manufacturers to know the chemical content of the ingredients they purchase in international markets.

- Although the composition of chemical feed-stocks is normally known by the chemical companies, manufacturers along the supply chains often do not know the origin of the ingredients they purchase to form their consumer products. Some recycled products, such as carpet padding that includes multi-colored recycled foam fragments glued together and resold, may include numerous flame-retardants, even if the flame-retardants have been phased out.

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Children carry far higher concentrations of numerous flame-retardants in their body tissues than adults do.

Boomerang Effect–Freedom to Export and Import

- In Section 12 of TSCA, it permits the export of domestically produced listed toxic substances, including flame-retardants, even if the exported chemicals are prohibited from use within the U.S.

- In other words, TSCA separates the right to produce and sell a chemical domestically from the right to sell and use that same chemical in other nations. Toxic flame-retardants phased out of use in the U.S. can still be added to products imported to the U.S., since no federal regulations ban imports and no labels report product ingredients to purchasers or consumers.

Regrettable Substitutions

- After decades of widespread use in consumer products, some manufacturers voluntarily agreed to end production, import and use of several brominated flame-retardants, including PentaBDE and OctaBDE (2004), and DecaBDE (2013).

- Other manufacturers have not agreed to EPA's requests to participate voluntarily in the phaseout, and all firms are free to produce and market chemicals of similar structure, environmental behavior, and toxicity.

- The historical sequential reliance on asbestos, PCBs, PBBs, chlorinated Tris, PBDEs, and now phosphate esters, demonstrates clearly a pattern of "regrettable substitution." As one danger was phased out from production and use, the replacement was guided by chemical industry choices rather than by any explicit intent to reduce environmental health hazards.[226]

Susceptible Populations

- TSCA offers ***no*** authority or requirement that EPA must identify and protect susceptible populations. These groups are well identified in the peer-reviewed scientific literature, and include children, infants, and fetuses.

- Children's immaturity, and rapid growth and development of crucial organ systems and functions, make them incapable of eliminating or breaking down flame-retardants. Their livers, kidneys, nervous and endocrine systems are all especially vulnerable to this class of chemicals.

- Children carry far higher concentrations of numerous flame-retardants in their body tissues than adults do. Thus, this combination of heightened biophysical vulnerability, rapid growth and development, and intense exposure place them at special risk.

EPA's 2013 Flame-Retardant Initiative

- In May 2013, EPA initiated risk assessments for 20 flame-retardants, focusing specifically on HCHB, TBB, TBPH, and TCEP, a chlorinated organophosphate. This action comes decades after scientists discovered these chemicals present in human and wildlife tissues.

Threat of Federal Pre-Emption

- Currently, TSCA allows states to adopt chemical regulations that are stricter than the federal government's. This authorization permits the states to be more health-protective of their citizens than the federal government.

- Current law also permits the states to prohibit the use of substances that the states deem too dangerous for use in their state.

- However, there always remains the threat that Congress could take away the states' right to pass stricter chemical laws than the federal government—in other words, Congress could "pre-empt" the states' right to pass stricter TSCA laws than the federal government's.[227]

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In California, the foam in baby products, including nursing pillows, strollers, high chairs, and baby carriers is required to meet the TB 117 standard.... This requirement has caused an increased use of flame-retardants in foam-filled residential and juvenile furniture, not just in California, but throughout the United States.

State Law and Regulation

- TSCA currently leaves states free to regulate toxic substances if EPA fails to act. EPA clearly has neglected flame-retardants over its 42-year life, so states have been free to adopt their own statutes and regulations.

- Since 2003, 19 states have adopted more than 93 chemical safety policies. Today, at least 15 state legislatures, including Connecticut's, are considering policies to phase out the use of toxic flame-retardants, including chlorinated Tris, in consumer products, such as children's products and home furniture.

- Numerous additional states are considering policies to identify chemicals of concern for children's health and to require makers of consumer products to disclose their use of these chemicals.[228]

California Regulations

TB 117

- California Technical Bulletin 117 (TB 117) is a state regulation that requires polyurethane foam in furniture and baby products to withstand a 12-second open flame test.

- This requirement has caused an increased use of flame-retardants in foam-filled residential and juvenile furniture, not just in California, but throughout the United States. Because flame-retardants comprise nearly 20 percent of some consumer products, it is no wonder that children in California have higher body burdens of these chemicals.

- The foam in baby products, including nursing pillows, strollers, high chairs, and baby carriers is required to meet the TB 117 standard. A 2011 study found that 80 percent of the 101 baby products with foam products tested contained a flame-retardant.[229]

TB 117-2013

- In February of 2013 California proposed a new draft rule (TB 117-2013) to reduce the use of flame-retardants in furniture and home insulation. This bill would require a smolder test for fabrics rather than an open-flame standard for foam. California AB 127 was recently signed into law to reduce the use of flame-retardants in plastic foam building insulation.

Mattresses

- California adopted mattress flammability standards in 2005, and the Consumer Product Safety Commission (CPSC) followed with a similar requirement in 2006. The CPSC rule requires manufacturers to ensure that mattresses may endure a 30-minute flame and sets a ceiling for the amount of heat that can be released from the mattress after a 10-minute exposure to the flame. Meeting the standard is accomplished by adding flame-retardant chemicals to the mattress surfaces or interior batting, or by incorporating internal retardant barriers.[230]

- Testing was conducted by the National Institute of Standards and Technology. Separate fire codes were adopted by the International Fire Code and the National Fire Protection Association (NFPA). NFPA's Life Safety Code applies to detention centers and dormitories without sprinkler systems.

- When the fire codes were adopted, they were criticized for not taking into consideration potential health effects and environmental contamination. CPSC claimed that it was possible to meet the standard using chemicals that pose little threat, although it declined to regulate the use of specific compounds.

Proposition 65

- The Safe Drinking Water and Toxic Enforcement Act of 1986, known as Proposition 65, requires the State of California to publish

When the fire codes were adopted, they were criticized for not taking into consideration potential health effects and environmental contamination.

Two flame-retardants "known to cause cancer" were added to the California list, TCEP in 1992 and TDCPP in 2011. About half of the residential couches in use in America are treated with TDCPP, indicating that a large percentage of the population may have increased cancer risks.

a list of compounds "known to cause cancer or birth defects, or other reproductive harm." Two flame-retardants "known to cause cancer" were added to the California list, TCEP in 1992 and TDCPP in 2011. Both compounds are phosphate esters, a chemical class that includes registered pesticides known for their neurotoxic potential.

- In California, products containing TDCPP must have a label stating, "*This product contains a chemical known to the state of California to cause cancer.*" About half of the residential couches in use in America are treated with TDCPP, indicating that a large percentage of the population may have increased cancer risks.[231]

- Those who make products with Prop 65-chemicals must provide "clear and reasonable warning" to consumers regarding the presence of the chemical. This list has now grown to include nearly 800 chemicals, and requires manufacturers to notify the state about the presence of these chemicals in their products, and warn consumers, normally by means of a label.

Other State Legislative Activity

- A recent senate bill to amend TSCA would pre-empt or prohibit state regulations such as Proposition 65. An exemption in the proposed federal bill might permit Proposition 65's notification and warning requirements to remain in effect. Many other state toxic laws and regulations would likely be similarly pre-empted by the language now proposed.

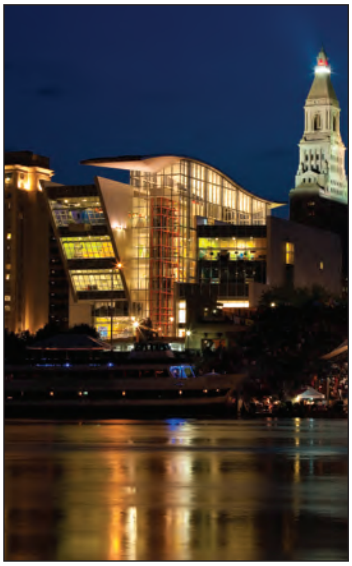
- With little Congressional effort to ban toxic chemicals, state legislatures have begun to pass chemical safety laws. In the past nine years, over 80 state chemical safety laws have gone into effect.[232]

- Individual states' regulations can motivate national voluntary removal of chemicals from the market. Several states initiated and enacted legislation to prohibit the use of PentaBDE and OctaBDE, including Illinois, Maine, Maryland, New York, Oregon, and Rhode Island, prior to industry phasing out these chemicals.

- States also prohibited the use of DecaBDE prior to the industry's decision to phase it out. Washington was the first state to pass a law banning DecaBDE in mattresses in 2008. Maine quickly followed Washington's action in the same year and expanded the ban to some electronics in 2010.

- Soon thereafter, California, Connecticut, Hawaii, Illinois, Massachusetts, Michigan, and Minnesota began considering a ban. Montana, New York, Oregon, and Vermont also began deliberations to restrict or ban the chemical, and numerous states began studies to monitor its use.

- By 2009, as the result of negotiations with EPA, the two U.S. producers of DecaBDE announced a voluntary phaseout of DecaBDE in the United States by the end of 2013.[233]



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Industry codes exist for the various sectors of the economy, such as building materials, electronics, and furnishings. All of these different codes influence where flame-retardants are used in our environment.

- Connecticut has proposed several bills to restrict the use of PentaBDE, OctaBDE, and DecaBDE in consumer products, but as of yet, these efforts have not been successful. Two house bills (2008 and 2009) and one senate bill (2009) have been introduced, specifically addressing the use of these chemicals in electronics and furniture.

Industry Standards Often Become Law

- The rise of chemical flame-retardants in our products, environments, and in human tissues grew not only in response to federal regulation, but also due to the growth of industry-specific codes and standards adopted by organizations such as the Underwriters Laboratories (UL).

- Industry codes exist for various sectors of the economy, such as building materials, electronics, and furnishings. All of these different codes influence where flame-retardants are found in our environment.

- The U.S. Green Building Council's (USGBC) history is a good example of this trend. The Council does not set its own standards to manage chemicals, but instead relies upon many other trade organizations, including the American National Standards Institute

(ANSI), the American Society for Testing Materials (ASTM), the International Code Council (ICC) and the National Fire Protection Association (NFPA). These are either trade associations or not-for-profit organizations with the purpose of certifying products' performance, functionality, and physical safety.

- The USGBC has not assessed chemical toxicity, environmental contamination or potential health effects following exposures. The USGBC standards strongly support energy conservation; that, in turn, demands increased use of insulating materials such as polyurethane foam products. The flammability of foam insulations has led to their treatment with high concentrations of chemical flame-retardants.

- USGBC standards in turn have been widely adopted into local, municipal, state, and sometimes federal laws and policies. The effect is that we are creating law and regulation to accomplish one goal—reduced fire risk or energy conservation—without considering the environmental or health implications. The result is that a billion pounds of flame-retardants now reside in built environments, and many of these chemicals are now being phased out of production due to their persistence and hazards to health.

- A final example is provided by the National Fire Protection Association's National Electrical Code (NEC) that is adopted as state law throughout the U.S. The NEC covers different types of wires and cables, their insulating materials commonly made from plastic, the conduits that run the wires together, and connectors. The majority of the NEC standards are taken from the Underwriters Laboratory code. Neither system of codification considers chemical persistence, life cycle, environmental fate, or chemical toxicity.

- Trade associations normally endorse or certify consumer products without assessing their health or environmental hazards. The codes and standards that have been adopted are not sufficient to protect human health or the environment.

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VII. Recommendations

For the Federal Government

■ Flame-retardants should only be used in high fire-risk situations.

Because exposures to flame-retardants carry their own set of health risks, flame-retardants should only be used in situations where the risk of injury from fire outweighs the risk from flame-retardant exposures. Examples of such high-risk situations include aircraft, marine vessels, cars, exterior building materials for use in fire-prone regions, and specialized clothing designed for those who face special fire risks.

■ Restrict the use of flame-retardants in infant and toddler products.

Recent toxicological studies show that flame-retardants pose the greatest risk to the normal growth and development of fetuses, infants and children. Infants and small children's body weight is so low that their exposures to flame retardants, in relation to their body weight, is simply too great. The health risks that all infants and children are experiencing, due to the federal law mandating that flame-retardants be in many of their products, far outweigh the risk of fire.

■ Restrict flame-retardant use in low fire-risk situations.

Most people live their daily lives in circumstances with low risk of fire. Current law allows—and in some circumstances requires—that untested fire-retardant chemicals be used to fireproof most components of our built environments and many consumer goods. For example, there is no need to add flame-retardants to thousands of consumer products, such as plastics used to package foods and beverages. The distinction between high and low fire risk situations should be carefully defined, and flame-retardants should be banned from all low-risk products.

■ The government should require that flame-retardants be tested for their health effects.

Most of the 200 flame-retardants in international commerce have not been adequately tested to reach the judgment that they are reasonably certain to be safe. Congress should require that flame-retardants be tested so their health and environmental effects are known. Testing requirements should apply to all flame-retardant chemicals, regardless of whether or not Congress exempted them from regulation under the Toxic Substance Control Act of 1976.

■ Flame-retardant risks should take into account susceptible populations.

EPA should prepare human exposure risk assessments for flame-retardants. EPA should take into account the vulnerability of susceptible populations, including children, infants, and fetuses; the elderly; and those with illnesses that might be exacerbated by exposures.

■ Testing should include chemical mixtures of flame-retardants.

Flame-retardants are commonly present as mixtures in our consumer products, and human tissues. Firemaster 550, a commonly used brand of flame-retardant in the United States, is a mixture of four distinct chemicals. Pesticides provide a model for this proposal, since EPA has completed "mixtures risk assessments" for organophosphate and triazine pesticides. Congress should demand toxicity testing of mixtures of compounds, such as the flame-retardant Firemaster 550.

Government should require industry to pay for testing.

The chemical industry, or product manufacturers who use and benefit from flame-retardants, should provide funding for the chemical testing initiative. Pesticide manufacturers, divisions of the same firms that manufacture flame-retardants, already are required to fund the testing of chemicals proposed for EPA approval, along with the costs imposed on EPA to review these data.

Products containing flame-retardants should be labeled as such.

Any product containing a flame-retardant should be labeled as such. Labels should state which flame retardant has been used.

Product certification programs should be established that verify the absence of flame-retardants—just as the Organic Food Program shows the absence of pesticides.

EPA should create a program that certifies the absence of flame-retardants from consumer products. This program could be similar to the organic food program that certifies that organic foods do not contain pesticides. This flame-retardant certification program could provide consumers with the opportunity to knowingly buy products that do not contain flame-retardants.

The federal government should require that corporations disclose their knowledge of significant hazards in their products.

Producers of flame-retardants should be required to disclose their knowledge of any hazard. Many corporations conduct their own hazard and risk assessments to understand and limit their liability, yet these data are not normally disclosed to the government.

As well, chemical companies should have the legal obligation to inform potential purchasers of flame-retardants that the federal government has found a significant hazard. Similarly, manufacturers should have a legal obligation to inform distributors and retailers about which flame-retardants are in their products.

- **EPA should require manufacturers to demonstrate safety using the "reasonable certainty of no harm" standard.**

To meet this burden, manufacturers should submit testing data that demonstrate a "reasonable certainty of no harm" associated with their products.

- **The federal government should establish a Registry of Flame-Retardants.**

EPA should be required to create and maintain a registry of flame-retardants. The purpose of the Registry would be to provide the public with knowledge about what flame-retardants are now in

production and what hazards they may pose to human health and the environment. It should also list what flame-retardants have been discontinued but are still in use, and their health effects.

- **The government should explicitly permit EPA to restrict production, use, export, and import of flame-retardant chemicals.**

Government should explicitly permit EPA to restrict production, use, export, and import of flame-retardant chemicals and products that contain them. For example, use of a flame-retardant should be allowed in aircraft interiors, while its use in children's sleepwear should be restricted. If a chemical is banned from production and use, the manufacturer should not be allowed to continue the sale of existing stocks.

- **Products containing flame-retardants should display a scannable barcode.**

Products that do contain flame-retardants should have a scannable barcode clearly visible that can be scanned using conventional cell phone technology. Scanning the code via cell phone would provide the consumer with additional information about the specific flame-retardants that were used, their potential health and environmental effects, and the proper disposal methods.

- **Cradle-to-grave producer responsibility.**

Nearly 10,000 municipal landfills contain a mixture of hazardous chemicals, including flame-retardants that have contaminated underlying soils and water. The chemical manufacturers have simply passed responsibility for these hazards along to local communities. Chemical manufacturers should be required to take financial responsibility for the environmental contamination caused by practices relating to disposal of their products.

Recommendations for States

- **States should pass laws that protect their citizens from flame-retardant exposures.**

Industry will always work to pre-empt states' legal authority to set safety standards that are more stringent than those adopted by the federal government. States should have the right to protect their citizens when the federal government fails to do so.

- **States should restrict flame-retardants in infant and toddler products.**

Recent toxicological studies show that flame-retardants pose the greatest risk to the normal growth and development of fetuses, infants and children. Infants and small children's body weight is so low that their exposures to flame retardants, in relation to their body weight, is simply too great. The health risks that all infants and children are experiencing, due to the federal law mandating that flame retardants be in many of their products, far outweigh the risk of fire.

- **States should require that products containing flame-retardants be labeled.**

Any product containing a flame-retardant should be labeled as such. Labels should include which flame-retardant has been used.

- **States should promote fire-prevention programs.**

States should invigorate their fire prevention programs. Promotion of fire prevention is the most effective, least expensive, least environmentally damaging priority our nation could pursue to reduce loss of health, life and property from fires. States should promote low-cost and highly effective early warning technologies. Smoke alarms save lives. They should be available to all, regardless of income status.

- **States should offer opportunities to recycle electronic products.**

Foam that contains flame-retardants remains a problem for landfills. State and local governments have primary responsibility for managing the disposal of solid and hazardous wastes. Most solid wastes in Connecticut are disposed of via incineration, but some are still placed in landfills. The broad failure to effectively recycle electronics, building materials, auto plastics and foam means that most products containing flame-retardants are released to the environment at the end of their life-cycle.

Recommendations for Individuals

- **Choose furnishings carefully.**

New furniture filled with polyurethane foam contains flame retardants, while furniture with polyester, down, wool or cotton fillings is unlikely to contain them. Avoid buying furniture labeled, "Complies with California TB 117" or similar language. Ask the manufacturer if its foam is flame-retardant-free, thereby creating an increased demand for untreated foam furniture.

- **Choose mattresses carefully.**

Major U.S. mattresses manufacturers do not disclose their use of flame-retardants, and a mattress labeled "Organic," "Eco-friendly," "Green," "Natural," or "Healthy" does not mean it is free of flame-retardants. There are some companies that will manufacture mattresses for you that do not contain flame-retardants; however, they may require a physician's letter.

- **Wash your hands often.**

You touch products with flame-retardant ingredients every day, perhaps dozens of times. The most common consumer products containing them include televisions, cell phones, computers, remote controls, kitchen appliances, home furnishings, vehicle interiors, paper, and other electronic equipment. Washing hands often, especially before eating, will reduce the amount ingested.

- **Prevent infants from mouthing products that may contain flame-retardants.**

  Prevent infants from mouthing plastic items that normally contain flame-retardants, TV remote controls, cell phones, and other plastic items.

- **Vacuum floors and carpeting often.**

  Indoor dust is often a source of exposure to flame retardants, and dust is commonly inhaled as fine particles. Infants may easily ingest dust as they crawl on the floor, placing hands and fingers in their mouths. PBDEs and other flame-retardants in carpet padding and furniture are released and bind to household dust. Vacuuming can help prevent this.

- **Prevent fire hazards.**

  Prevention is the most effective, least costly, and least contaminating strategy you can follow to avoid loss from fires. Fire-proofing your environment with toxic flame-retardant chemicals might add only 20 seconds to the time you need to escape your home in the event of a fire. Remember that the retardants cause products to smolder, which causes them to release potent toxic gases before bursting into flames.

  - Be certain you have working fire alarms in each of your rooms, hallways, basement and attics. Change your alarm batteries each year and test the alarms once a month.
  - Keep a working fire extinguisher near the kitchen, basement, and in the master bedroom.
  - Do not smoke indoors. Cigarettes continue to be the leading cause of furniture fires.

- If you have children, be exceptionally careful to store lighters and matches in a place inaccessible to them.
- Have a separate escape plan for every member of your family. Practice the escape plan to make children comfortable.
- Have your furnace, water heater, chimneys, and wood stoves inspected annually by professionals to determine proper combustion and ventilation.
- Do not store highly flammable liquids or gases indoors. These include propane tanks and gasoline cans.

Recommendations for Corporations

Corporations should disclose to the government any significant hazards from their products.

Many corporations conduct their own hazard and risk assessments to understand and limit their liability, yet these data are not normally disclosed to the government. Producers of flame-retardants should be required to disclose their knowledge of any hazard.

Corporations should demand that their suppliers inform them about which flame-retardants are in their supply chains.

Manufacturers should require their distributors and retailers to disclose any flame-retardants in their products.

Corporations should actively manage what chemicals are in their products.

Corporations should adopt and publish criteria for acceptable chemical ingredients in their products, and work with their suppliers to restrict or phase out the use of chemicals that are persistent, that bioaccumulate, or are toxic.

- **Corporations should consider having product lines that are flame-retardant-free—just as organic food lines are pesticide-free.**

Many of the nation's organic food companies are owned by the largest non-organic parent companies. Major producers of building materials, electronics, plastics, textiles and paper products should launch flame-retardant-free lines of their own brands.

The building sector is moving rapidly to develop product lines that contain less-persistent and less-toxic chemicals. The paint industry carries both low-VOC emitting paints and traditional solvent-based paints.

- **Corporations should adopt the principles of Green Chemistry to drive choices about chemical acceptability and substitution.**

It is especially important to avoid replacing one hazardous chemical with another that is poorly tested.

- **Corporations, where appropriate, should be responsible for product disposal.**

Corporations should adopt standards of responsibility for proper disposal of products containing flame-retardants once they reach the end of their useful life-cycle. This may mean working collaboratively with other firms in a product sector to establish recycling centers, or requesting that some especially hazardous products be returned directly to a store. For example, HP pays for the return of printer cartridges to dispose of any remaining inks and recycle plastic materials.

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