THE AMERICAN COUNCIL ON SCIENCE AND HEALTH PRESENTS

Brominated Flame Retardants: A Burning Issue

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A Burning Issue

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Executive Summary

A class of brominated flame retardants known as polybrominated diphenylethers (PBDEs) is under assault from environmental activists and regulators both in the United States and overseas. Flame retardants give people more time to escape a fire by delaying flashover, the explosive-like eruption of flames responsible for most of the fatalities and property damage in residential fires. PBDEs are particularly effective flame retardants and have long been widely used in the manufacture of televisions and other electrical equipment, furniture, and mattresses.

Fire retardants truly save lives. Their use in television cabinets alone is estimated to save 190 lives a year in the U.S. In the United Kingdom, where materials used in many home furnishings must be fire-resistant, researchers reckon the regulations have spared about 1,150 lives and prevented almost 13,500 injuries over the course of a decade.

Nevertheless, U.S. and European regulators have effectively banned two of the three most prominent PBDE flame retardants. An assortment of states, environmental groups, and foreign governments, moreover, is seeking to ban the third one (i.e., decaBDE) as well, even though there is no credible evidence that the chemical represents a danger to humans or the environment. Numerous studies, in fact, have concluded that our exposure to the compound is minimal and does not pose an adverse health risk for people at expected exposures.

Current evidence shows that the benefits of PBDE flame retardants, in terms of lives saved and injuries prevented, far outweigh any demonstrated or likely negative health effects from their use.

Introduction

Life-saving flame-retardant chemicals are under assault. Ignoring the vitally important role these compounds play in preventing or slowing fires, environmental activists advocate banning certain flame retardants on the grounds that biomonitoring studies have found trace amounts of the chemicals in humans, including in breast milk. They hope to get various governmental authorities in the U.S. and overseas to impose strict prohibitions on these flame-retardant chemicals.

At issue is a class of brominated flame retardants known as polybrominated diphenylethers (PBDEs). Within this group, three commercial mixtures of PBDEs are: penta-, octa-, and decaBDE. Each product is a mixture of diphenyl ethers with varying degrees of bromination. (ECB 2002b) These particular PBDEs have widely and frequently been used as flame retardants in furniture foam (pentaBDE); plastics for TV cabinets, consumer electronics, wire insulation, and backcoatings for draperies and upholstery (decaBDE); and plastics for personal computers and small appliances (octaBDE). The chemicals increase valuable escape time in cases of fire by slowing both ignition and the rate of fire growth. (USEPA 2005a)

Efforts to ban these chemicals are deadly serious business. In the U.S., someone dies in a fire every two hours and ten minutes, and the vast majority (85 percent) of these non-firefighter, civilian deaths occur in home fires. The fire death rate is 14.8 persons for every one million Americans. (BFRIP 2002) In view of the public debate and regulatory reviews of PBDEs, a look at some flame-retardancy facts is in order.

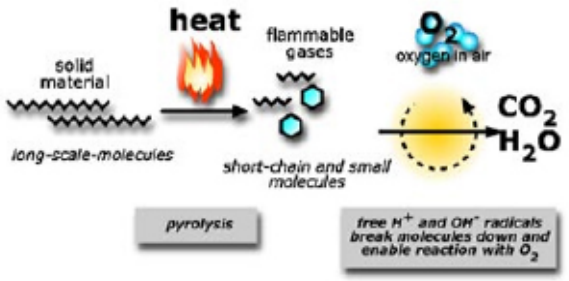
How Flame Retardants Work

Chemical flame retardants have been around since Roman times, when they were used to prevent siege towers from catching fire. The first flame-retardant patent was issued in England in 1735, and the use of these compounds to make plastics flame resistant began in the early 1970s. To understand how flame retardants work, it's

necessary to understand how things burn. (BSEF 2005a)

Solid materials don't burn directly. In a process known as pyrolysis, heat must first decompose the materials, releasing flammable gases. When these gases burn with oxygen in the ambient air, visible flames appear. To be more specific (Figure 1), what are known as high-energy "free radicals" (i.e., H+ and OH- in the gas phase) break down molecules, freeing carbon atoms that react with oxygen (O2) and burn, releasing both carbon dioxide (CO2) and water (H2O). (EFRA 2005)

Figure 1. Pyrolysis: How Things Burn



Source: EFRA 2005

Flame retardants, in effect, remove the free radicals, reducing both the generation of heat and the production of flammable gases. This either prevents a fire from erupting or at least slows the combustion process considerably. (EFRA 2005)

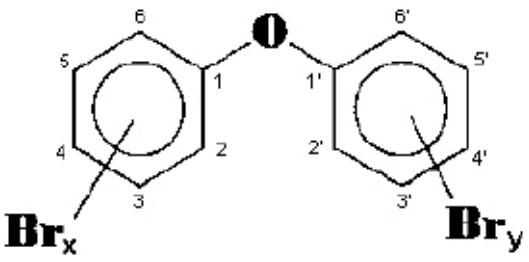
Flame retardants thus give people more precious time to escape a fire prior to flashover. (Thomson 2004) Flashover occurs when a relatively small, slowly developing fire, spreading systematically across adjacent fuel surfaces within a room, suddenly transitions to a much larger and more dangerous fire in which all flammable surfaces, including ceilings, walls, and floors, are involved. It is estimated that roughly 20 percent of reported fires in the United States that transition to flashover are responsible for 80 percent of the fire deaths and property damage in buildings. (BFRL 2004) By delaying flashover, flame retardants can mean the difference between living and dying. (Thomson 2004) Flame retardants, in fact, can increase the amount of escape time by a factor of 15, meaning that instead of having just 10 seconds, say, to flee with your life, flame retardants may give you as much two and a half minutes to escape. (BSEF 2005a)

Brominated flame retardants (BFRs) are a family of chemicals commonly used in domestic and industrial appliances and equipment such as computers, TV's, mobile phones, furniture, insulation boards, mattresses, and many others. Nine in 10 electrical and electronic appliances contain BFRs. BFRs are also used in textiles for upholstered furniture. (BSEF 2005a)

Among different BFRs, polybrominated diphenyl ethers (PBDEs) are particularly useful for several reasons: 1) they release their flame-retarding bromine (Br) atoms in the same general temperature range at which many household items combust; 2) they combine easily with different plastics and other materials in the manufacturing process, making the resulting products (e.g., TV sets) fire resistant; and 3) they are highly cost-effective. (BFRIP 2002)

DecaBDE derives its effectiveness in retarding flame from the bromine atoms on the diphenyl oxide molecule (Figure 2). Bromine is one of the few elements able to provide flame retardancy in the gas phase of combustion. DecaBDE's high bromine content makes it very effective in retarding flame and also highly cost-efficient. (BFRIP 2002)

Figure 2. Chemical Formula of Brominated Diphenyl Ethers



Source: WHO 1994

About four-fifths of decaBDE production is used in high-impact polystyrene electrical or electronic products, such as television cabinets. (Hardy 2002) These applications are important in improving the safety of consumer products since potentially flammable polymers are in close contact with possible ignition sources, notably electricity. (Hays 2003) PBDEs typically comprise 5 to 30 percent of a product's overall weight. (CSOR 2004)

DecaBDE also is used to flame-retard upholstery fabric and textiles found in homes, offices, and motor vehicles. The chemical is encapsulated in latex and applied as a fabric back-coat, which significantly limits potential releases and exposures via direct contact with the flame-retarded surface. DecaBDE, however, is an additive flame retardant, which means it is physically combined with the material instead of being chemically combined. This creates the possibility that decaBDE may diffuse out of the treated material. (Hays 2003, BFRIP 2002, ECB 2002)

Residential Fires Cost Lives

Fires in the U.S between 1995 and 2004 cost 4,023 lives and injured another 21,704 on average per year (excluding the events of Sept. 11, 2001), according to the U.S. Fire Administration. In 2004 alone, an estimated 1,550,500 fires nationwide killed 3,900 persons and injured an additional 17,785; direct financial losses approached $9.8 billion. (USFA, 2005a) Residential fires represented about 27 percent of all fires in 2004 and 78 percent of structure fires. Of all civilian fire fatalities (i.e., non-fighter fatalities), almost 82 percent occurred in the home, and about 84 percent of these fires were in single-family homes or duplexes. (NFPA, 2004)

Young children and the elderly are often the victims of residential fires, accounting for 22 percent of all fire-related deaths and injuries in 2002. Residential fires injured or killed an estimated 2,490 children age 14 or younger, with children under the age of 5 representing 56 percent of child fire casualty deaths, according to the U.S. Fire Administration. Fires and burns were the third leading cause of unintentional fatal injuries to children age 14 or younger in 2002; they were also the third leading cause of unintentional injuries to infants, and the 12th overall cause of unintentional injuries to children age 14 or younger. (USFA 2005b) An estimated 2,320 older adults were injured or killed in residential fires in 2002. Smoking was the leading cause of these fires (25 percent), which typically ignited upholstered furniture and bedding. (USFA 2005c)

Internationally, the total cost of fires to society is estimated at about 1 percent of the world's gross domestic product (GDP), with property losses alone amounting to 0.2 percent of global GDP. Not surprisingly, a great deal of research has gone into preventing the spread of flame using barriers and flame retardants. The use of flame retardants, coupled with governmentally mandated fire-safety regulations and strict building codes, are reflected in the varying percentages of deaths per fire from continent to continent (Table 1). The lowest fire fatality rates are in North America and Australia, followed by South America and Africa. European fire fatalities are slightly above the worldwide average, but the rate of fire-related deaths in Asia is triple the global mean. (Harding, Crompton 2000)

Continent	Population (millions)	Fires per Year (millions)	Fire Deaths per Year (thousands)	Deaths per Fire* (percent)
Europe	720	2.2	25.0	0.011
Asia	3,660	1.0	30.0	0.030
North America	470	2.3	6.5	0.003
South America	340	0.5	2.5	0.005
Africa	780	0.8	5.0	0.006
Australia	30	0.1	0.3	0.003
Total	6,000	6.9	69.3	0.010

*Calculations added.

Table 1. Global Fires and Fire Deaths by Continent **Source: Harding and Crompton 2004**

Flame Retardants Save Lives

A study of the safety benefits of decaBDE and other brominated flame retardants (BFRs) in the U.S. found that an estimated 190 lives are saved annually because of the use of these flame retardants in television cabinets alone. Their use in electrical wire/cable insulation is estimated to save an additional 80 lives per year, and their application to draperies likely saves 10 more lives a year. All told, decaBDE and other flame inhibitors save an estimated 280 lives in the U.S. each year. (BFRIP 2002)

In studying the relationship between incidence of fire-related deaths and injuries and the use of flame retardants, the United Kingdom is perhaps the world's best venue, principally because in November 1988 it began instituting rules requiring all fabric and polyurethane foam used in the construction of furniture and mattresses be fire resistant. The rules were later expanded to other filling materials and also applied to used furnishings for resale. The UK may thus be considered a touchstone against which to assess fire-safety regulations promulgated in other countries. (Surrey 2000, 2002, 2005)

Surrey University's Polymer Research Center, which has published a series of studies relating to Britain's flame-retardants regulations, finds substantial benefits in reduced numbers of serious fires, reduced fatal and non-fatal injuries, and reduced financial losses since the introduction of the "Furniture Fire Safety Regulations 1988." The risk of death in residential fires in the UK, for example, dropped from 17 per million people per annum (pmp pa) in 1988 to 10 pmp pa in 2005, a 41 percent reduction. It is estimated that about half of this reduction (or around 20 percent) relates to the increased use of effective residential smoke alarms and around half (or about 21 percent) can be ascribed to the 1988 fire-safety regulations. The effect of reduced tobacco smoking in the UK over the period was considered negligible. (Surrey 2005)

Cumulatively, from 1988 to 2002, it is estimated the 1988 UK furniture regulations alone saved 1,150 lives and prevented 13,442 injuries (Figure 3). Smoke alarms in Britain and the upholstered furniture regulations combined prevented an estimated 44,314 residential fires, saved 4,287 lives, and prevented 39,257 non-fatal injuries. As for property damage, the savings from 1988 to 2000 is calculated at £182 million per year (or around $300 million) or a 12-year total of about £2.2 billion (or about $3.6 billion). (Surrey 2005)

If current trends continue, the rate of UK residential fire deaths is likely to decline to between 5 and 6 pmp pa by 2010 to 2015, which would place Britain in the "best of class" group of countries with the best fire-safety records. (Surrey 2005) (California has already achieved this distinction, having implemented statewide fire-safety standards for residential upholstered furniture in 1976. California is the only state in the nation with such home-furnishings requirements, although federal fire-safety standards do apply to commercial furniture. [Hays 2003, CPSC 2001])

In Britain, fire-safe furniture and smoke alarms

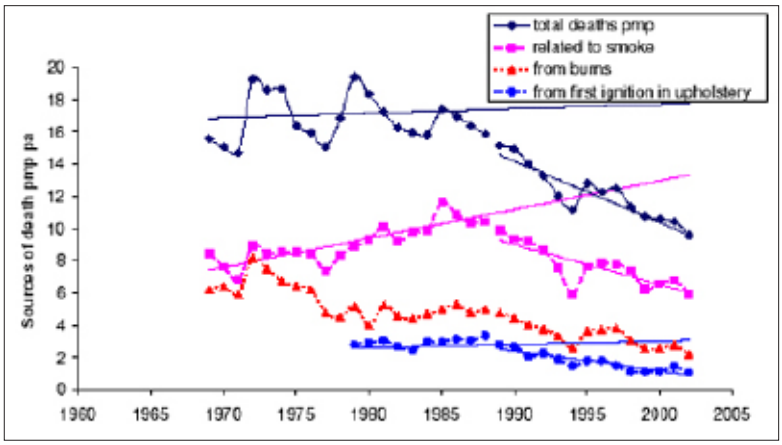


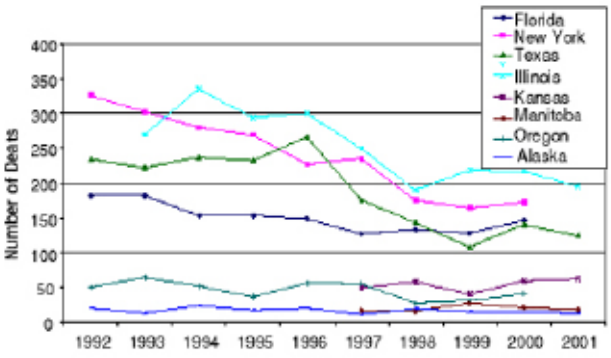
Figure 3. Pre- and Post-1988 Trends in UK Fatal Fire Injuries in Dwellings
Source: Surrey 2005

are expected to bring residential fire fatalities down to between 300 and 360 per year over the next decade from an actual 898 fire deaths in 1988 and 561 in 2002. By comparison, in France, which has no residential furniture fire-safety regulations and where the penetration of smoke alarms in residences is near zero, residential fire deaths for an equivalent population are calculated at 680. (Surrey 2005, Deheuvels 2004)

The University of Surrey researchers, reviewing U.S. fire data, reached a startling conclusion:

> The progressive decline in the risks of death in fire in the USA appears to correlate well with the steady increase in the number (and probably the effectiveness) of smoke alarms in US residences....
>
> However, despite the progressive decline in national US residential fire death rates, the US sustains a much higher risk of residential fire death in comparison to the UK. Some care is required when making international comparisons because it also is clear that there can be very wide variations of fire risk within countries and within regions. In the USA, state-to-state comparisons [Figure 4] indicate that the risk of death in fire can vary from below 5 pmp pa to over 30 pmp pa. This same wide range of risk exists in Europe and in the rest of the world. It is clear that climate, lifestyle, and cultural differences may account for some of this variation but it also true that sufficient exceptions exist to indicate that the effectiveness of good fire protection regulation and the presence of good fire countermeasures are also important factors.
>
> By adopting furniture fire safety legislation at the federal level, combined with ongoing promotion of fire alarm installation and maintenance, it might be possible to eventually reduce the national average death rate due to fire in the US to 6 pmp pa. If this was achieved the number of additional lives saved in 2000 would be around 7.6 pmp pa. or 2,139 people per year. (Surrey2005)

Figure 4. Trends in State Fire Deaths in the U.S. from 1992 to 2001



Source: Surrey 2005

Efforts to Ban PBDEs

Both European and U.S. regulators have taken steps to ban pentaBDE and octaBDE, while permitting continued use of the third prominent PBDE flame retardant, bdecaBDE.

Following an exhaustive 10-year risk assessment that included the evaluation of 588 studies, the European Union (EU) decided on Oct. 13, 2005 to exempt decaBDE from its "Directive on the Restriction of Hazardous Substances," meaning the compound may continue to be used as a flame retardant in its 25 member countries.* The EU risk assessment had concluded that the use of decaBDE does not pose risks to humans or the environment. (BSEF 2005c) Since the risk assessment of decaBDE has concluded that there is at present no need for measures to reduce the risks for consumers beyond those which are being applied already, the EU found that decaBDE can be exempted from any restrictions on its use until further notice. Should new evidence lead to a different conclusion of the risk assessment, the decision would be re-examined and amended, if appropriate. (EC 2005) The EU left standing an earlier directive requiring the separation of decaBDE, as well as other BFRs, from electrical and electronics (E&E) equipment waste prior to recovery and recycling. (BSEF 2005c)

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* EU member countries: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the Netherlands, and United Kingdom.

The EU banned the marketing of two other BFRs – namely, pentaBDE and octaBDE – as well as articles containing more than 0.1 percent of either chemical, effective Aug. 15, 2004. (EU 2003) Citing a risk to breast-feeding infants, a series of EU Risk Assessment Reports expressed concern that the bioaccumulative properties (i.e., the tendency of a substance, such as a toxic chemical, to accumulate in various tissues of a living organism) of pentaBDE and octaBDE could cause concentrations in breast milk to rise. It further said risks to infants from exposure to pentaBDE and octaBDE via cows' milk is likely to be similar to or greater than that from human breast milk. (ECB 2000, ECB 2002a, ECB 2002b, ECB 2003a, ECB 2003b)

The U.S. Environmental Protection Agency (EPA) cited the EU risk assessments in deciding to issue a *de facto* ban on the production or purchase of penta- and octaBDE in the United States. Using a regulatory device known as a "Significant New Use Rule," the EPA since Jan. 1, 2005 has required prior notification of any plans to manufacture or import pentaBDE and octaBDE. (USEPA 2004)

In particular, the agency called for specific measures to limit risks from pentaBDE because of "concerns for effects on the local aquatic (sediment) and terrestrial environment as a consequence of exposure arising from polyurethane foam production [and] concerns for secondary poisoning to the environmental spheres both locally and regionally as a consequence of exposure arising from production and/or use of polyurethane foams." (ECB 2000, USEPA 2004) For octaBDE, the EPA cited the EU's concern about the risk of "secondary poisoning via the earthworm route for the hexabromodiphenyl ether component in the commercial octabromodiphenyl ether product from the use in polymer applications." (ECB 2003a, USEPA 2004)

The EPA states the case against PBDEs thusly:

> Although use of flame retardants saves lives and property, there have been unintended consequences. There is growing evidence that PBDEs persist in the environment and accumulate in living organisms, as well as toxicological testing that indicates these chemicals may cause liver toxicity, thyroid toxicity, and neurodevelopmental toxicity. Environmental monitoring programs in Europe, Asia, North America, and the Arctic have found traces of several PBDEs in human breast milk, fish, aquatic birds, and elsewhere in the environment. Particular congeners [i.e., related chemical substances], tetra- to hexabrominated diphenyl ethers, are the forms most frequently detected in wildlife and humans. The mechanisms or pathways through which PBDEs get into the environment and humans are not known yet, but could include releases from manufacturing or processing of the chemicals into products like plastics or textiles, aging and wear of the end consumer products, and direct exposure during use (e.g., from furniture). (USEPA 2005a)

The agency in promulgating its "Significant New Use Rule" explained that the lower brominated PBDEs (tetraBDE, pentaBDE, and hexaBDE) found in the commercial pentaBDE and octaBDE products are "the congeners most often detected in the environment and for which human health and environmental concerns are greater. These factors, taken together, raise concerns for potential adverse effects in people and wildlife over time if these substances should continue to be produced, released, and built up in the environment." (USEPA 2004, USEPA 2006)

The EPA action followed a voluntary phase-out by Great Lakes Chemical Corp. (GLC), the only U.S. manufacturer of pentaBDE and octaBDE, which ceased production of both chemicals by the end of 2004. In announcing its decision to act preemptively, GLC (now part of Chemtura, Inc.) explained that the EPA has concluded that PBDEs do not constitute a risk to the public, while conceding that there is growing public concern about the persistence and bioaccumulation of penta

products. Accordingly, GLC decided to transition away from pentaBDE in "an orderly manner, years ahead of any legislatively-mandated deadlines." (The EPA considers a chemical with a half-life of more than 120 days to be "persistent" and less than 60 days to be not a concern. It considers a chemical with a bioaccumulation factor of more than 5,000 to be "bioaccumulative" and less than 1,000 to be not a concern.) (GLC 2004, USEPA 2004)

Separately, the EPA's Integrated Risk Information System (IRIS), a database of human health effects from exposure to various substances, says penta- and octaBDE are not classifiable as to human carcinogenicity because no human data or animal data are available. (IRIS 2006a, IRIS 2006b) DecaBDE, however, is considered a "possible human carcinogen," based on no human data but instead limited evidence of carcinogenicity in animals – specifically, significantly increased incidences of neoplastic liver nodules in male and female rats and increased incidences of hepatocellular adenomas or carcinomas (combined) in male mice. (IRIS 2006c)

In assessing risk for health effects other than cancer and gene mutations from chronic chemical exposure, an EPA working group coined new terminology (e.g., reference dose, or RfD). NOEL (also referred to as NOAEL) is the highest experimentally determined dose without a statistically or biologically significant adverse effect. In cases in which a NOEL has not been demonstrated experimentally, the term lowest-observed-adverse-effect level (LOAEL) is used. The RfD is a benchmark dose operationally derived from the NOAEL by consistent application of order-of-magnitude uncertainty factors (UFs). The modifying factor (MF) is an additional uncertainty factor whose magnitude depends on the professional assessment of the completeness of the overall data base and the number of species tested. Ranging from zero to 10, the default value for the MF is 1. (USEPA 1993)

Beyond the federal manufacture and import restrictions, a number of states have either enacted legislation or are considering proposals banning the use of pentaBDE and octaBDE. Notably, however, a California State Senate research report concluded, like the EU's multiyear risk assessment, that decaBDE does not pose a risk to public health and thus should not be proscribed. (CSOR 2004)

The EPA, meanwhile, is evaluating potential PBDE substitutes through its New Chemicals Program and its Design for the Environment Program's Furniture Flame Retardancy Partnership with private industry. In the case of pentaBDE, the working group says no single alternative is likely but it has identified 14 chemical formulations that are potentially viable substitutes in large-scale production of low-density flexible polyurethane foam. EPA assessed the hazards, potential exposures, and tendency to bioaccumulate and persist in the environment for the chemicals. The industry panel continues to look for other flame-retardant compounds. (USEPA 2005b)

Additionally, the EPA is engaged in the Voluntary Children's Chemical Evaluation Program (VCCEP), working with chemical manufacturers to provide data to enable the public to understand the potential health risks to children associated with certain chemical exposures. Through VCCEP, industry-sponsored risk assessments for pentaBDE, octaBDE, and decaBDE were developed to evaluate the potential risks to children and prospective parents from potential exposure scenarios. In September 2005, EPA issued its Data Needs Decision on PBDEs, asking manufacturers to provide the needed data by volunteering to conduct a mix of tests. (USEPA 2005a)

Substitutes for decaBDE also are being studied for use to electronic enclosures, such as TV set backs, and textiles, as well as replacements for pentaBDE in flame retardant furniture foam. The most cost-effective non-halogenated substitutes for decaBDE high-impact polystyrene (e.g., TV backs) involve changing the resin system and the use of phosphorous-based flame retardants. The

most cost-effective non-halogenated substitutes include: blends of polycarbonate and acrylonitrile-butadiene-styrene, using the flame retardant bis-phenol A diphosphate; polycarbonate, utilizing phosphate esters; and blends of high-impact polystyrene and polyphenylene oxide, which includes the flame retardant resorcinol bis diphenyl phosphate. Other substitutes such as metal, wood, or enclosures based on polylactide are possible but are not widely employed because of cost and performance issues. (Lowell 2005)

In regard to textiles, the most common chemically applied decaBDE substitutes available for natural cellulosic fibers such as cotton, wool, rayon, and linen are dimethylphosphono (N-methylol) propionamide (phosphonic acid) and tetrakis (hydroxymethyl) phosphonium salt (or chloride) compound with urea. For synthetic fabrics such as acrylic, acetate, nylon, and polypropylene, some decaBDE substitutes are available, but they often have limited durability because of their water solubility and tendency to wash out during laundering. (Lowell 2005)

The Swedish government has said it intends to propose a restriction on the use of decaBDE in textiles, furniture, and cable applications. DecaBDE's use in automobiles and in electrical and electronic equipment would not be affected. The government further said it is launching a study of two other BFRs – hexabromocyclododecane (HBCD), used mainly in textile coatings and thermal insulation foams, and tetrabromobisphenol A (TBBPA), primarily used in laminates (e.g., epoxy resins) for printed wiring boards – with an intent to ban the chemicals. It was taking the action, it said, because it felt the EU was moving too slowly in regard to the two compounds. (EBFRIP 2005)

Australia decided in June 2005 to commence a process to assess the potential effects on public health and the environment of certain BFRs, including decaBDE. China is preparing legislation similar to that approved by the EU concerning the handling of E&E waste containing BFRs. And Norway, which isn't an EU member, is considering legislation to partially restrict the use of decaBDE. Some foreign governments have objected to the Norwegian proposals, however, and the final outcome remains undecided. (EBFRIP 2005)

Warnings from Environmental Groups

Environmentalists have made PBDE flame retardants a *cause célèbre*. Greenpeace, for instance, has held demonstrations to get electronics makers to stop using the chemicals. (Sandoval 2005) The Swedish Society for Nature Conservation has expressed opposition to the use of brominated flame retardants (BFRs), claiming they are absorbed and stored in the body and pose "serious health consequences that are a threat to the development and well-being of future generations." (SSNC 2005) A pair of U.S.-based environmental groups have found BFRs in dust samples swiped from computers (Hines 2004), and Los Angeles-based Environment California has criticized the EU for failing to act on decaBDE, citing concerns that the compound breaks down into "its more toxic cousins octa and penta." (Environment California 2003)

A report by Northwest Environment Watch in Seattle found decaBDE in 24 of the 40 women tested, with 10 of the women carrying deca levels above 1 part per billion. The highest level detected was 4.3 ppb. It said even the deca congener alone exceeds the levels of total PBDEs typically found in European and Japanese populations. Levels of deca in the most exposed residents of the Pacific Northwest are comparable to those of Swedish electronics dismantlers, who are occupationally exposed to decaBDE. (NEW 2004)

Washington Physicians for Social Responsibility maintain that PBDEs, which share chemical properties with banned PCBs, are ubiquitous in our environment. This group states that studies have linked these chemicals to serious health effects, including memory impairment, and learning and behavioral problems in laboratory animals, and that they have also been associated with disruption of thyroid hormone balance, non-

Hodgkin's lymphoma in humans, and a variety of cancers in rodents. (WPSR 2004)

People for Puget Sound cite studies that have found PBDEs in Puget Sound orcas, salmon, ospreys, Columbia River fish, and Northwest human breast milk. The studies they cite refer to levels found in orca whales 2-10 times higher than those found in other whales around the world, and the levels found in breast milk were 20 to 40 times higher than levels found in Europe and Japan. (PPS 2004)

Canadian and Norwegian scientists recently reported finding PBDEs in the fat tissue of adult and subadult female polar bears sampled between 1999 and 2002 from sub-populations in Arctic Canada, eastern Greenland, and Svalbard, and in males and females collected from 1994 to 2002 in northwestern Alaska. (Muir 2005)
The Environment California Research & Policy Center, a San Francisco public interest research group (PIRG), maintains decaBDE "poses a threat to human health" because it decomposes into forms that are "more toxic and more easily absorbed by the body" and also because it "may be neurotoxic," affecting the nervous system and impairing motor skills. "Deca," the PIRG report added, "is one of many potentially hazardous chemicals that are in widespread use, due to a failed national policy that presumes chemicals are safe until proven beyond a doubt to cause harm." (Kucher 2004)

Human Exposure to PBDEs

Studies have found decaBDE in human tissue, but the route of exposure is unknown. (CSOR 2004) Recent data suggests that PBDE body burdens continue to rise in North American wildlife and humans, and that PBDEs levels among individuals within a population vary widely, by approximately 50-fold. The reasons for this variability are not well understood, but likely relate to differences in exposure and host differences that affect uptake and elimination. (CSOR 2004)

Levels of PBDEs among residents of North America are approximately 40 to 70 times higher than those of individuals in Europe or Japan. This disparity is likely a result of the fact that more than 95 percent of the world's use of the penta-BDE technical mixture (whose congeners are highly bioaccumulative) is in the Americas. (CSOR 2004)

Current total PBDE levels in U.S. blood samples are the highest reported worldwide to date, according to a University of Texas study, with 2 pooled samples measuring 61.7 and 79.7 parts per billion (ppb) lipid. In a series of 39 individual analyses, the range was 4.6 to 365.5 ppb, with a median of 29 ppb and a mean of 52.6 ppb. (Schecter 2005)

A study comparing potential PBDEs inhalation exposures of three groups of workers (i.e., clerks working in front of computer screens full-time, workers at an electronics dismantling plant, and a control group of hospital cleaning workers) found decaBDE in the blood of individuals from all three groups. Plasma levels of decaBDE were significantly higher in the electronics dismantling workers than in the other two groups, apparently resulting from inhalation of particle-bound decaBDE in the air of the dismantling plant, as high ambient levels of particle-bound decaBDE were recorded at the plant. Electronics dismantling involved grinding plastic goods in a shredder. DecaBDE in the blood of cleaning workers and clerks was presumed to be due to ingestion of food contaminated with decaBDE. The total median PBDE concentrations in the serum from

workers at the electronics-dismantling plant, clerks, and cleaners were 37, 7.3, and 5.4 pmol/g lipid weight, respectively. The results show that decaBDE is bioavailable (i.e., the ability of a drug or other substance to be absorbed and used by the body) and that occupational exposure to PBDEs occurs at the electronics-dismantling plant. (Sjödin 1999)

It has been suggested that the main sources of exposure of the general population to decaBDE are likely to be inhaled air and contact with dust at home or in the office. The efficiency of absorption of decaBDE following inhalation has not been investigated, but a large proportion of inhaled particles containing decaBDE are likely to be ultimately swallowed and only a small proportion of the decaBDE in these particles is likely to be absorbed. (Searl 2003)

In experimental animals fed standard laboratory diets, pentaBDE mixtures can decrease circulating thyroid hormone and liver vitamin A concentrations. A substantial number of pregnant women and their children have marginal vitamin A status, potentially increasing their risk of adverse effects to pentaBDE exposure. The results support the concept that marginal vitamin A status in pregnant women may increase the risk for PBDE-induced disruptions in vitamin A and thyroid hormone homeostasis. (Ellis-Hutchings, 2006)

To assess blood concentrations of PBDEs and polychlorinated biphenyls (PCBs) and their polychlorobiphenylol (OH-PCB) metabolites in humans with a high seafood intake, researchers obtained samples from pregnant women in the Faroe Islands in 1994-1995 and from their children at 7 years of age to examine maternal transfer of the compounds to their child, age-dependent metabolism, and temporal changes. Children at 7 years of age, it found, are exposed to PCBs at levels only slightly below those of their mothers, and the increased 4-OH-CB107 concentrations in children could be due to age-related differences in PCB metabolism. The PBDE concentrations were similar in both mothers and their children. The main persistent organic pollutant concentrations in the children are most probably due to other environmental exposure than maternal transfer. (Fangstrom 2005)

The EPA has launched a project plan, including a dedicated webpage (www.epa.gov/oppt/pbde), to further assess and evaluate PBDEs and human health and to weigh possible substitutes. In unveiling the project, the federal agency noted that PBDEs level in humans and the environment are generally higher in North America than in other parts of the world and cited potential concerns about liver toxicity, thyroid toxicity, developmental toxicity, and developmental neurotoxicity. (USEPA 2006b)

The U.S. Department of Agriculture, meanwhile, is conducting research on the absorption, disposition, metabolism, and excretion (ADME) of PBDEs. Studies of ADME in rats have been conducted on commercial pentaBDE, octaBDE, and decaBDE mixtures. Rodent ADME studies have also been conducted on BDE congeners 47, 99, 100, 154, and 209. Studies in rats are planned for BDEs 153 and 183, along with further study of BDE-209. (USEPA 2006b)

Studies Find No Health Risk

At least four leading institutions – two international, and two U.S.-based – have reviewed decaBDE for potential health risks to humans, and all four evaluations concluded that exposures to decaBDE were minimal and not likely to pose an adverse health risk. (Hays 2003) (CSOR 2004)

Specifically, the World Health Organization (WHO) evaluated the manufacture and formulation of decaBDE into polymers and concluded that exposure of the general population to decaBDE is insignificant. (WHO 1994) The National Academy of Sciences (NAS) and the Consumer Product Safety Commission (CPSC) assessed the use of decaBDE in textiles (National Academy of Sciences 2000; Babich and Thomas 2001), and the European Chemicals Bureau examined exposures to decaBDE via the general environment. (ECB 2002) These four evaluations concluded that exposures via the respective pathways did not pose any adverse health risks to the general population. (Hays 2003)

Additionally, the California Senate Office of Research (CSOR) reviewed the potential hazards from decaBDE and reached the following conclusion:

> Based on an analysis of the likely potential harm to humans posed by decaBDE and the known human exposures to this chemical, it does not appear that human exposure to decaBDE is occurring at a level that is likely to be unsafe for human health or development given the current level of scientific knowledge. At this time, it would be premature to add decaBDE to the list of banned PBDEs contained in AB 302 [a California law banning the sale of products containing two classes of PBDE – pentaBDE and octaBDE – as of 2008]. (CSOR 2004)

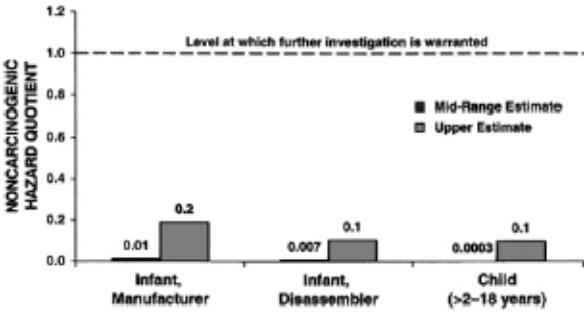
As for the exposure of infants and children to decaBDE, current levels of decaBDE in the U.S. are not likely to represent an adverse health risk for children (Figure 5). The study looked at six different pathways by which children might become exposed to decaBDE; it then combined these into three exposure scenarios, which aggregated all exposures for a given population: (Hays 2003)

1. Child (0–2 years) ingesting breast milk from a mother who manufactures decaBDE, mouthing decaBDE-containing plastic electronic products, mouthing decaBDE-containing fabric, and being exposed via the general environment,
2. Child (0–2 years) ingesting breast milk from a mother who disassembles electronics, mouthing decaBDE-containing plastic electronic products, mouthing decaBDE-containing fabric, and being exposed via the general environment,
3. Child (>2–18 years) being exposed via the general environment. (Hays 2003)

Like the findings of the WHO, CPSC, the EU, and the NAS, each of which concluded that decaBDE does not pose a health risk to humans, this assessment of the exposure of infants and children in the U.S. to decaBDE was consistent with their conclusions that current levels of exposure do not endanger the health of infants or children, including those ingesting breast milk from mothers occupationally exposed to decaBDE. (Hays 2003)

German researchers furthermore found the reported levels of decaBDE detected in breast milk by Veith et al. (2005) would not be expected to be hazardous to infant health. There is a substantial margin of safety in the predicted intake of decaBDE by breastfeeding babies and EU standards. There is also a substantial margin of safe-

Figure 5. Hazard Quotients for Children's Exposure to DecaBDE



Source: Hays 2003

ty in comparison to the lowest effects level reported by Viberg et al. (2003) for developmental toxicity in mice. (BfR 2005)

There are no reports of any adverse clinical health effects in humans associated with touching, inhaling or ingesting decaBDE. In an NAS review, no data were identified on immunological, neurological, reproductive, developmental, or carcinogenic effects of decaBDE following dermal exposure, inhalation exposure, or oral exposure. In animal studies, no clinical signs of toxicity or death occurred in rats that received single gavage doses as high as 5,000 mg/kg (NAS 2000), which is equal to 5,000,000 ppb.

Similarly, a U.S. Consumer Product Safety Commission (CPSC) risk assessment for residential upholstered furniture concluded decaBDE was not likely to present a hazard to consumers. In both adults and children, dermal exposure was the primary route of exposure to decaBDE; the contribution from inhalation of particles was negligible. In all cases evaluated, the Hazard Index (HI) was less than 1 – that is, the potential exposures were below those of concern. (CPSC 2001)

The California Senate Office of Research also found insufficient evidence to warrant a ban of decaBDE in California. It found that human exposure to decaBDE is not occurring at a level that is likely to be unsafe for human health or development given the current level of scientific knowledge. They concluded that at this time, it would be premature to ban PBDEs. (CSOR 2004)

DecaBDE has not been shown to be a hazard to human health in anything close to the dosages that have been observed or that are likely to occur, according to a submission to Washington State authorities by the Boeing Company. No study, it noted, has found the compound to be toxic, although vague concerns have been raised about neurological damage in high dosages in experimental animals. DecaBDE's half-life of 12 days in humans cannot be considered persistent. (Thomson 2004)

The results of animal experiments further suggest that most ingested decaBDE is rapidly excreted through the gastrointestinal tract. Both animal and human data indicate decaBDE is largely removed within a few days of exposure and that there is little long-term retention of decaBDE in tissue. Evidence further suggests the commercial form of decaBDE is not absorbed by the gut and passes out of the body quickly through feces. (Searl 2003) (Raupe 2003)

Neither is decaBDE a cancer risk. According to the U.S Public Health Service's Subcommittee on Flame Retardants, there is "no evidence that [decaBDE] posed either a non-cancer or cancer hazard regardless of exposure route." (USPHS 2001)

Another risk assessment of exposure to decaBDE and the potential human health effects reached the following conclusions:

- Levels of exposure of the general population to decaBDE are much too low to give rise to an adverse effect on health.
- Levels of exposure of workers recycling electrical goods appear to be much too low to give rise to an adverse effect on health.
- Levels of exposure of computer technicians and office workers using electrical equipment are unlikely to be substantially greater than for other members of the general population and are much too low to give rise to an adverse effect on health.
- Historical levels of exposure during the production of decaBDE may have been higher; however, there is little evidence to suggest that exposure to decaBDE during production has been an important cause of ill health in exposed workers.
- The presence of decaBDE in the blood of recycling workers confirms that they are exposed to decaBDE and is suggestive of slightly higher levels of exposure to decaBDE than typical for the general population.
- The presence of decaBDE in the blood of recycling workers does not indicate that they are being exposed to quantities of decaBDE that are likely to be hazardous to health. (Searl 2003)

DecaBDE in the Environment

DecaBDE, largely because of its physical properties, does not pose a significant risk to the environment. Sunlight does not degrade decaBDE. (Jafvert and Hua 2001) DecaBDE is poorly soluble, and its presence in natural waters is mainly associated with suspended particulate matter, which is an important carrier for all PDBE species. (de Boer 2003) DecaBDE has a strong affinity to bind to organic carbon in the water column and sediment. (Hardy, 2002a) Most studies of the concentrations of PBDE in the water column have failed to find detectable levels of these compounds. DecaBDE does not accumulate in wildlife or food and unlike other persistent organic chemicals has not been reported to occur in wildlife or sediments. (Searl 2003)

Concerns have been raised over the potential for decaBDE to act as a source for tetra- and pentaBDE. Researchers at the University of Victoria, Canada conclude that the distribution of "penta species" found in the environment near urban and industrial regions arise from a weighted mix of commercial penta- and octaBDE mixtures in present use rather than from environmental debromination of decaBDE. (Rayne and Ikonomou 2002)

Dutch researchers report similar results. In a study of the occurrence of PBDEs in the aquatic environment of the Netherlands, UK, Ireland, and the southern North Sea, sediment core analyses confirm a decaBDE increase. However, a parallel increase of penta-mix-related congeners was not found, except in one Norwegian core. Because indications of increasing nona- and octaBDEs were not found, it is unlikely that penta- and hexaBDEs are being formed from decaBDE, unless at a very slow rate. The results support the view that decaBDE in the environment is not responsible for the presence of penta-product components in biota (fish, breast milk, etc.). (de Boer 2001)

Most important, PBDEs occur naturally. Several dozen are known to be marine natural products – mainly sponge metabolites – and at least two such natural PBDEs are identical to synthetic PBDEs. These two natural PBDEs were recently isolated from whale blubber (from a True's beaked whale, *Mesoplodon mirus*) and shown by C-14 isotopic analysis to be naturally produced and not synthetic. The PBDEs having both natural and anthropogenic origins are methoxylated PBDEs MeO-BDE-17 and MeO-BDE-68. (Reddy 2004, Teuten 2005) The significance of the findings are this: when PBDEs are found in fish and marine mammals, it is entirely possible, even likely, that they are of natural origin. DecaBDE itself, however, has yet to be found to be a marine (sponge or bacterial) natural product.

Conclusions

There is no credible medical or scientific basis upon which to support a decaBDE flame-retardants ban. Studies have failed to demonstrate any health risks to the general population. Banning flame retardants, though, has the dire potential to increase the risk of death from fire and raise the number of associated injuries.

DecaBDE's flame-retardant and life-saving properties are undeniable. By reducing the incidence of fires and, perhaps more important, by giving occupants valuable extra time to flee a fire, PBDEs are a clear benefit to public health in reducing fire injuries and fatalities in the United States and worldwide. Finding trace amounts in the human body or in environmental samples is not an indication of harm. Even studies of human breast milk failed to show adverse effects on infants or children.

Furthermore, when interpreting biomonitoring data as a measure of the background level of chemical exposures from the environment, Dennis Paustenbach and David Galbraith offer an important caveat in *Biomonitoring: Measuring Levels of Chemicals in People – and What the Results Mean*: to wit, since in most cases the source of the chemical being measured in the biological samples will not be known, there is also a large risk of misinterpreting the data, and perhaps the most common misperception is that the mere detection of a chemical in our bodies suggests a health hazard rather than simply providing a measure of exposure. (Paustenbach 2005)

The efforts to ban decaBDEs, in sum, are misguided. Were such bans adopted, they would have the potential to engender very real and potentially tragic threats to public health from fires that would otherwise have been prevented or delayed with the use of products incorporating brominated flame retardants. By any measure, the benefits to public health and safety of decaBDEs outweigh the risks related to their production and use.

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