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## Flame Retardants Under Fire

I kept thinking of Yogi Berra's line "It's déjà vu all over again" as I pored over dozens of scientific papers, reports, and articles on flame retardants and talked with experts over the past month. Current concerns about certain flame retardants—especially brominated flame retardants—bear striking resemblance to concerns expressed in the 1970s about other compounds that were designed to protect us from the risks of fire.

Polychlorinated biphenyls (PCBs) were banned in the late '70s after these flame-resistant insulating liquids used in electronic equipment were found to be carcinogenic, persistent in the environment, and bioaccumulative—that is, they build up in the food chain. Poly *brominated* biphenyls (PBBs), flame retardants that are chemically very similar to PCBs but made with bromine instead of chlorine, were banned in the '70s after a tragic mix-up in Michigan.

Today, other flame retardants—also made with bromine and also identified as persistent, bioaccumulative toxins—are in the news. Concerns about *polybrominated diphenyl ethers* (PBDEs) emerged in 1999, when Swedish researchers reported that levels of these chemicals in human breast milk had increased 60-fold between 1972 and 1997. Follow-up studies in the San Francisco Bay Area found PBDE levels in breast milk that were six to ten times higher than levels in Sweden. At the same time, laboratory studies suggested that the health effects might be similar to those of PCBs—ranging from interference with brain development to altered hormone function and cancer.

The manufacturers and industry associations representing these flame retardants tell us that the chemicals are safe, but weren't they saying the same thing about PCBs and PBBs three decades ago? Meanwhile, we're using orders of magnitude more brominated flame retardants today than we were when PBBs were banned.

This article tackles the issue of flame retardants—and especially brominated flame retardants—in building materials, furnishings, and office equipment. We'll describe how different flame retardants work, review applications of flame retardants, examine environmental and health concerns surrounding these compounds, discuss regulatory actions, and, finally, provide some far-reaching recommendations for reducing the use of the most dangerous flame retardants. These recommendations will likely be among the most controversial that *EBN* has ever put forth. It could be a rough ride, but hop aboard!

### The Benefits of Flame Retardants

Before we get too far into the health and environmental risks associated with flame retardants, it is important to point out their many, very significant benefits. From 1992 through 2001, an average of over 4,200 people were killed by fires each year in the United States and 25,000 injured (not including victims of the attacks on September 11, 2001),



*Damage from a candle-ignited fire that destroyed a campus fraternity house in Amherst, Massachusetts—brominated flame retardants probably prevented this television from fully igniting.*

according to the U.S. Fire Administration of the Department of Homeland Security. More people are killed by fires in the U.S. than from all natural disasters combined. In 2001, exclusive of September 11, there were over a half million structure fires in the U.S. with a total property loss of \$10.6 billion.

Accidental fires are also a significant source of environmental contaminants and toxins, including persistent organic pollutants (POPs) such as dioxins and furans. Relative to the quantity of material burned, pollution emissions are far higher from an uncontrolled structure fire than from a municipal incinerator, because the combustion temperatures are typically lower and oxygen may be limited.

Because flame retardants make products less likely to catch fire, a strong argument can be made for their use—in the interest of safety and protection of property. Use of flame retardants is driven to a very large extent by life-safety codes that are designed to protect us and our property by regulating how quickly a fire will spread, how much smoke it will produce, and whether it will self-extinguish.

## Understanding Flame Retardants

To understand how flame retardants work, we need a little understanding about how materials burn. When we see flames from a piece of burning wood, what we are seeing is not actually the *wood* burning. Rather, that flame is the combustion of flammable gases that are released from the thermal decomposition of the wood (a process called *pyrolysis*). With wood, as the temperature reaches about 300°F (150°C), these volatile gases (a mixture of short-chain hydrocarbons, hydrogen, and oxygen) are released as smoke. At about 500°F (260°C), hydrogen (H) and hydroxy (OH) radicals break off from the hydrocarbon molecules, leaving carbon atoms that react with oxygen in the air—combustion. This combustion process releases carbon dioxide, water vapor, and heat—which fuels the pyrolysis.

The role of flame retardants is to impede the ignition of flammable materials and slow the spread of a fire. They are effective primarily during the *ignition* phase of a fire. Once a fire is fully engaged, flame retardants have little effect. Thus, flame retardants should be thought of as only one element in a multi-part strategy for preventing, allowing for escape from, and extinguishing fires.

Halogenated flame retardants (those containing bromine and chlorine) function primarily by removing the H and OH radicals during the ignition phase of a fire. When heated, halogenated flame retardants release bromine or chlorine radicals; these react with the hydrocarbon molecules in the flammable gas mixture (smoke) to create hydrogen bromide (HBr) or hydrogen chloride (HCl). These gases then react with the high-energy H and OH radicals, releasing water vapor and the lower-energy Br and Cl radicals—which may remain available to repeat the cycle. To summarize, the halogen radicals released as the material heats up interfere with gas-phase combustion, slowing or blocking ignition.

Brominated and chlorinated compounds differ in their flame-retardant properties. Bromine-hydrocarbon bonds are weaker than chlorine-hydrocarbon bonds, so bromine radicals are released more easily as the material is heated. These bromine radicals are also released over a narrower temperature range, so they tend to be more concentrated as a fire starts and, thus, more effective at stopping the fire.

Some halogenated flame retardants are mixed with plastics or synthetic fibers and held in place physically; we refer to these as *additive* flame retardants. Others are chemically bonded to the polymer molecules during the manufacture of plastics; these we call *reactive* flame retardants. As we will see, this distinction affects how easily the flame retardants can escape from a plastic (without a fire) into the environment or your building.

Other flame retardants function in quite different ways. Phosphorous flame retardants act on the solid phase of the combustible material, rather than the gas phase. When heated, phosphorous reacts to form phosphoric acid, which chars the solid. This charring inhibits pyrolysis (the decomposition and release of volatile gases), so less fuel is fed to the fire. As with brominated flame retardants, some phosphorous flame-retardant compounds are mixed with the substrate and physically held in place (additive), while others are chemically bound to the substrate's molecules (reactive).

Halogenated organic phosphorous compounds, including tris (chloropropyl) phosphate (TCPP) and tris (chloroethyl) phosphate (TCEP), rely on both the gas-phase flame retardant properties of halogens (in this case, chlorine) and the

solid-phase action of phosphorous.

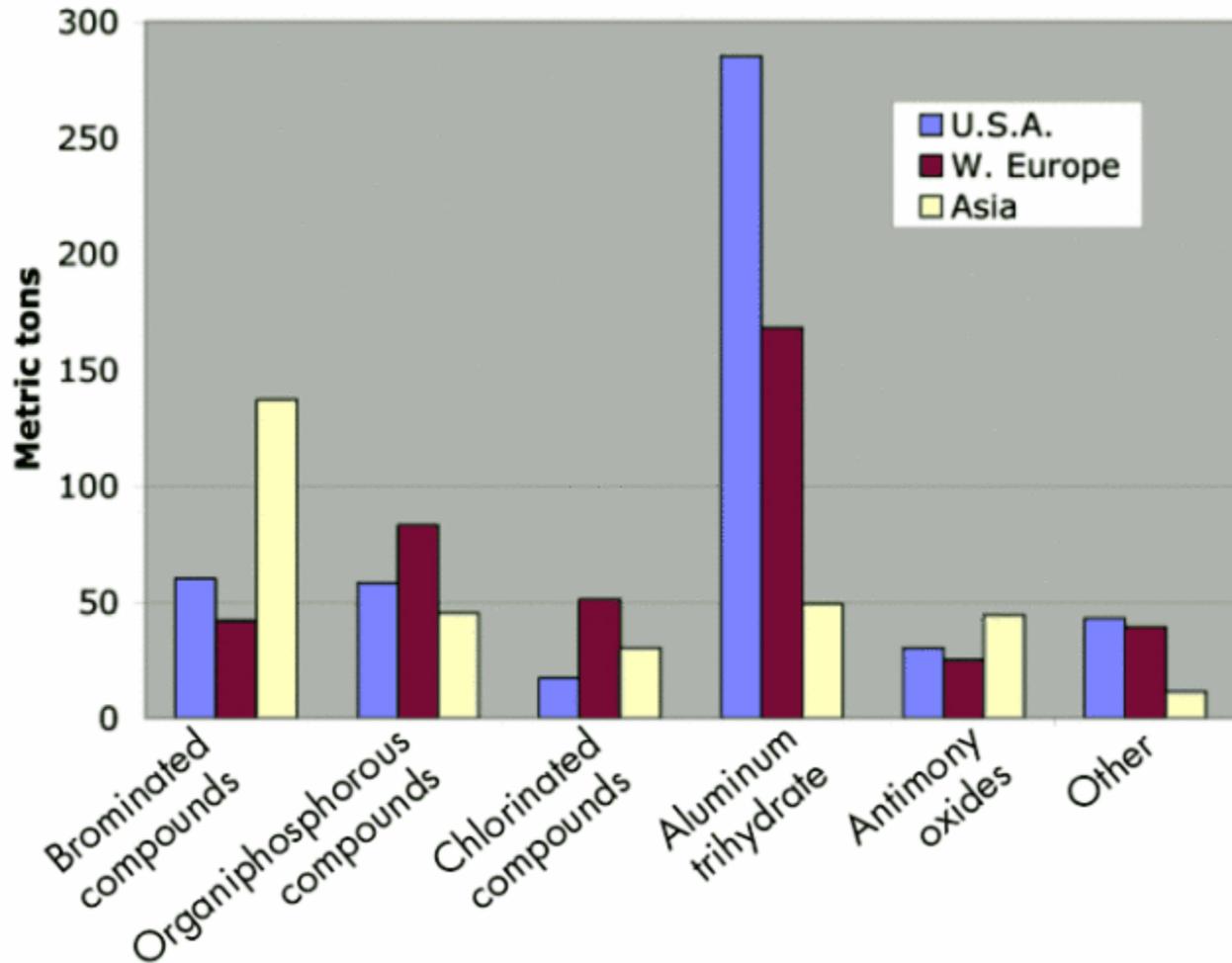
Most inorganic flame retardants, including aluminum trihydrate (the most widely used flame retardant in the U.S.), magnesium hydroxide, and boron compounds, function through a combination of mechanisms. Aluminum trihydrate decomposes to aluminum oxide at about 390°F (200°C), forming a protective, nonflammable layer on the material's surface and releasing water. The water (as steam) is a nonflammable gas that inhibits flames, and the whole reaction is endothermic—that is, it absorbs energy—so it helps to cool the material and retard pyrolysis. Magnesium hydroxide works the same way but at somewhat higher temperatures—around 570°F (300°C). Because fairly large quantities of inorganic flame retardants are required to provide protection, these materials also have the effect of *diluting* the combustible material. (Noncombustible filler materials like gypsum also have this effect, but they aren't categorized as flame retardants.)

Nitrogen-based flame retardants such as melamin cyanurate (MC) provide a cooling effect, and they release a noncombustible gas (nitrogen) that dilutes the oxygen atmosphere around the material.

Some materials, such as antimony trioxide ( $\text{SbO}_3$ ), are not flame retardants on their own but function as *synergists* with halogenated flame retardants. Antimony trioxide acts as a catalyst to speed the release of bromine or chlorine radicals. It also reacts with the halogen radicals, forming antimony halogens that help remove the high-energy H and OH radicals, thus helping suppress the fire.

Intumescent coatings provide a quite different form of protection against fire. They are applied as coatings on wood, plastic, steel, and other materials, and when heated they expand to form a fire-resistant and insulating layer. Intumescent coatings can keep flammable materials from burning, but they can also protect nonflammable materials, such as structural steel, from heating up and weakening in the event of a fire, thus preventing or delaying structural collapse.

Chart 1. Flame Retardants by Type and Region – 2001 (thousands of metric tons)



As can be seen, the chemistry of flame retardants is complex. More than 175 flame retardant compounds are currently on the market, and the industry is worth over \$600 million dollars per year in the U.S. and nearly \$2 billion worldwide, according to the European Flame Retardants Association (see chart).

Flame retardants are far more common than most of us realize. Many materials contain quite high levels of flame retardants: cellulose insulation is about 20% flame retardant by weight, plastic television and computer cases are often 10–20%, and polyurethane foam cushioning can be up to 30%. Some materials have very low levels of flame retardants: polystyrene foam insulation is typically 0.5–2.0% HBCD (hexabromocyclododecane) by weight. Manufacturers of products with less than 1% flame retardant might not list it on the Material Safety Data Sheets (MSDS), since it falls below the threshold for required listing.

Some products use flame retardants as secondary components, which can render an MSDS misleading. For example, of the half-dozen MSD sheets *EBN* obtained for polyisocyanurate insulation, only those from Dow Chemical listed any flame retardants, leaving the impression that some polyiso is formulated so as not to require flame retardants. Polyiso does contain flame retardants (about 5% by weight), but because those chemicals are formulated into the polyol component used in production of the foam, some manufacturers apparently believe that they do not have to list them separately.

Most of the current concern about flame retardants focuses on brominated flame retardants (BFRs). Brominated flame retardants are widely used for plastics, due to their effectiveness and relatively low cost. More than 75 of these compounds or mixtures are recognized commercially. Some are generic compounds made by a number of manufacturers; others are proprietary formulations that differ slightly from product to product. The best known BFRs today are PBDEs, HBCD, and TBBPA—full names and descriptions are in Table 2.

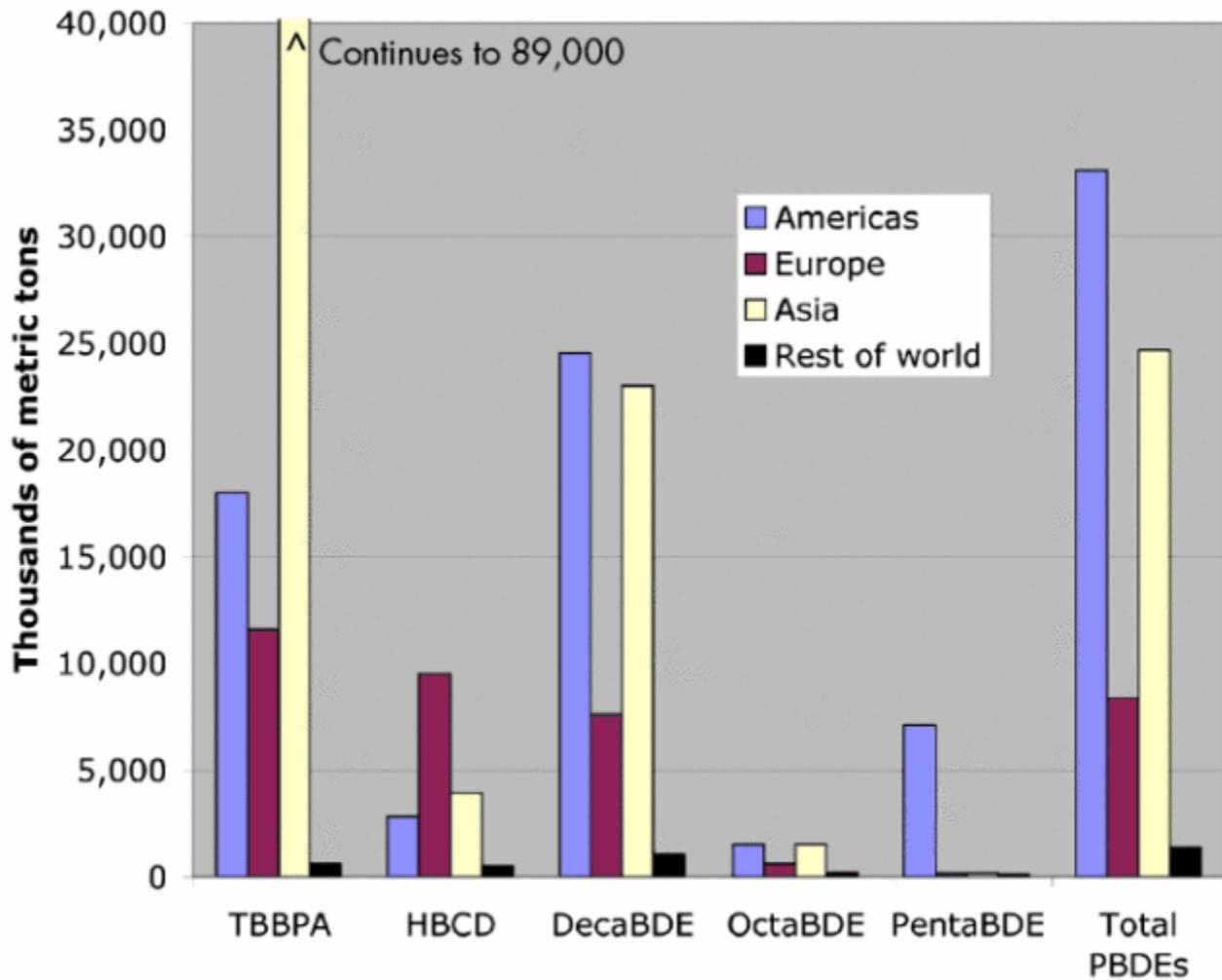
## History of Brominated Flame Retardants

While PBDEs are receiving a lot of attention today among health and environmental experts, this isn't the first time brominated flame retardants have gained notoriety. In the early 1970s, the closely related polybrominated biphenyls (PBBs) were commonly used in a wide range of plastics, including polycarbonates, polyesters, polyolefins, and polystyrenes. PBBs were removed from the U.S. market after a notorious 1973 accident in which 2,000 pounds (900 kg) of a PBB known by the trade name FireMaster FF-1 (hexabromobiphenyl) was inadvertently mixed with animal feed in Michigan, resulting in widespread health and environmental problems. An estimated 8,000 to 12,000 Michigan residents were directly exposed to PBBs through meat, milk, butter, cheese, and eggs, and a total of 30,000 head of livestock and 1.6 million chickens ultimately had to be destroyed following this accident. Several years after the accident, only 10% of the Michigan population did not have detectable levels of PBBs in their blood, and many residents in Michigan—and elsewhere—still carry that toxic burden. At the time of the accident, 4.9 million pounds (2.2 million kg) of FireMaster FF-1 were produced annually in the U.S. Production of that chemical was terminated in 1974, but octa- and deca- forms of PBB (compounds with eight and ten bromines, respectively) were produced—exclusively for export—until the late-1970s.

Another brominated flame retardant, tris(2,3-dibromopropyl) phosphate, or tris-BP, commonly used in children's sleepwear, was banned by the Consumer Products Safety Commission in 1977 after studies showed it to be carcinogenic and mutagenic in laboratory animals.

## Brominated Flame Retardants Today

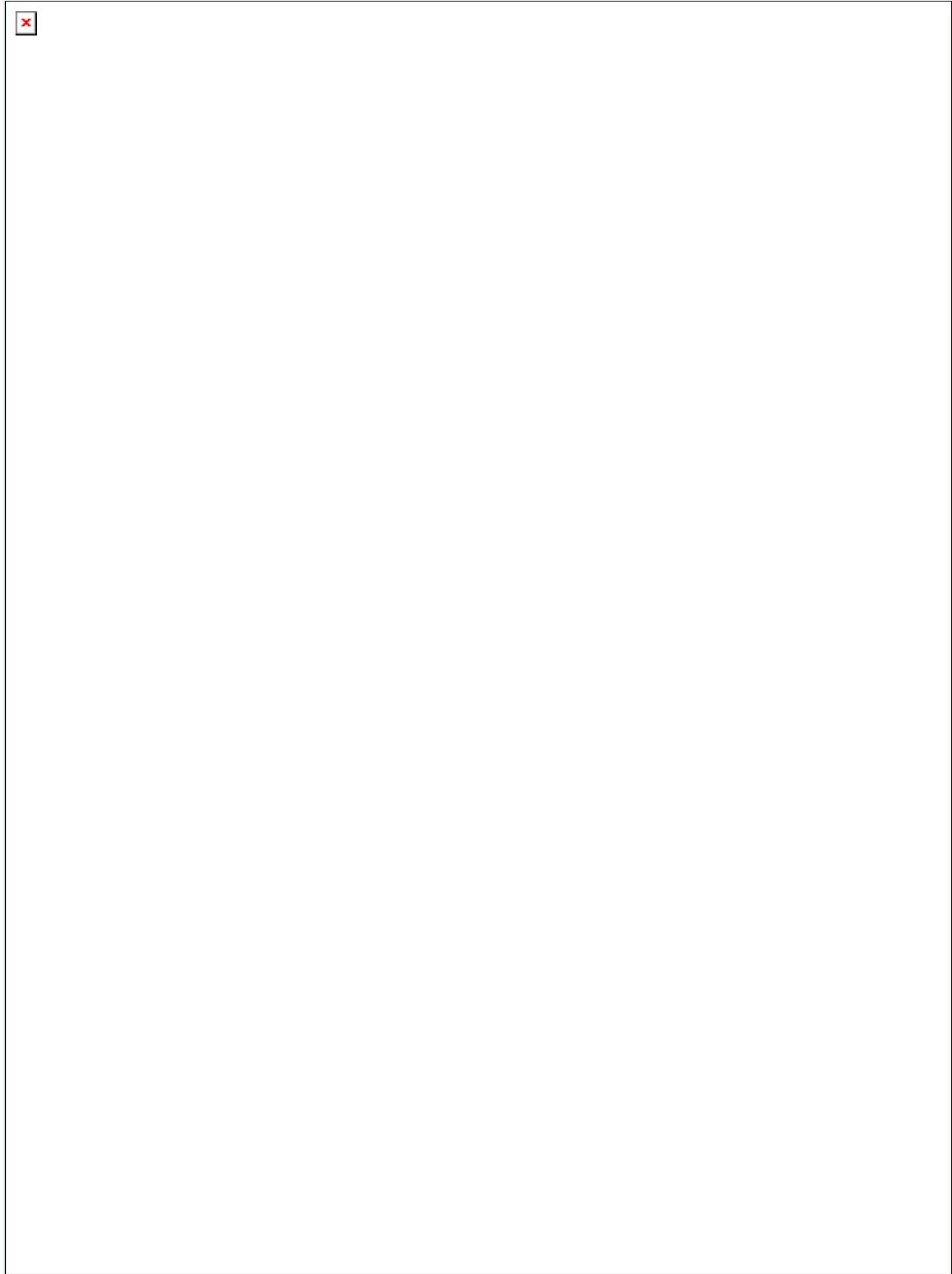
Chart 2. Brominated Flame Retardant Production by Region in 2001 (metric tons)



Worldwide, approximately 450 million pounds (200,000 metric tons) of the five most common BFRs were produced in 2001, according to the Bromine Science and Environmental Forum (an industry association). These five compounds—TBBPA, HBCD, and three PBDE mixtures (decaBDE, octaBDE, and pentaBDE)—account for the vast majority of BFRs sold. The breakdown of production by compound and region is shown in Chart 2. As can be seen, there are significant regional differences in the use of these flame retardants; decaBDE is the most common BFR in the Americas, while TBBPA is most common elsewhere. Three manufacturers dominate world production of BFRs: Great Lakes Chemical Corporation of West Lafayette, Indiana; the Albemarle Corporation of Baton Rouge, Louisiana; and the Israeli company Dead Sea Bromine Group.

### Flame Retardant Applications

<b>Table 1. Selected Applications and Flame Retardant Use in Buildings</b>	
<b>BUILDING INSULATION</b>	
Polystyrene (XPS and EPS)	Virtually all expanded polystyrene is produced with HBCD at a concentration (or filling rate) of 0.5 to 2.0% by weight.
Polyisocyanurate and spray polyurethane	The most commonly used flame retardant is TCPP, a non-brominated compound with chlorine and phosphorous as the active ingredients.
Fiberglass and mineral wool	No flame retardants
Cellulose	Borate compounds or ammonium sulfate at a filling rate of 18-20%
<b>CARPET AND FURNITURE PADDING</b>	
Polyurethane flexible foam	PentaBDE (phasing out in 2004), TCPP, and numerous other brominated and phosphorous-based flame retardants are used at filling rates of up to 30%.
<b>DRAPERIES AND OTHER TEXTILES</b>	
Synthetic draperies	DecaBDE, HBCD and other brominated and phosphorous-based flame retardants are used.
Polyester upholstery fabric	DecaBDE and other brominated and phosphorous-based flame retardants
<b>WIRE AND CABLE</b>	
PVC	Antimony trioxide, a synergist, is added to help the chlorine in the PVC serve in a flame-retardant capacity.
Polyethylene	Various brominated and phosphorous-based flame retardants are used.
Fluoropolymer (Teflon®)	No added flame retardants required (see <i>EBN</i> Vol. 13, No. 3)
Sources: German Federal Environmental Agency, Bromine Science & Environmental Forum, BFR producers, product manufacturers	



The largest quantities of brominated flame retardants are used in hard plastic computer casings, printers, televisions,

and other electrical and electronic (E&E) components. Significant quantities are also used in building materials and furnishings. A few building-related applications and the most commonly used flame retardants are listed in Table 1. Additional application areas are listed in Table 2, which is organized by flame retardant.

Unfortunately, it can be difficult for a specifier to find out just which flame retardants are used in a given product. While some materials are consistent in their flame-retardant use—polystyrene insulation is nearly always made with HBCD, for example—other materials differ from manufacturer to manufacturer in the flame retardants used, so generalities cannot be made. Unless (or until) there are consistent reporting requirements for flame retardants—even in small quantities—*informed decision-making about products relative to flame-retardant use will be difficult.*

As concerns about flame retardants, especially brominated flame retardants, grow in the coming years, some manufacturers will differentiate themselves based on the elimination of chemicals that are deemed harmful. Office furniture manufacturer Herman Miller, for example, has a very active *Design for the Environment* program that is using the cradle-to-cradle approach developed by McDonough Braungart Design Chemistry to eliminate hazardous components, including halogenated flame retardants. The company is trying to eliminate all halogenated compounds from new products being developed, and they will then work at redesigning existing products, according to Gabe Wing, a chemical engineer with the company. Both the Aeron and Mirra chairs are free of halogenated flame retardants, and the company is working actively with chemical manufacturers and component suppliers to eliminate halogenated flame retardants from other products and components, including polyurethane foam that is widely used in office seating.

Carpet tile and fabric manufacturer Interface, Inc. has been working to eliminate the use of BFRs companywide, according to Jim Hartzfeld of Interface, but they still have a long way to go. So far the company has eliminated all BFRs at its Canadian carpet tile plant, which makes product with PVC backing, and has cut BFR use by 75% in its LaGrange, Georgia plant, which produces non-PVC carpet tile. On the fabric side, comparable progress has been made over the past five years to eliminate BFRs, according to Hartzfeld, but new safety regulations may actually reverse some of that progress by mandating greater flame resistance.

### Environmental and Health Concerns with BFRs

Given the very clear evidence of health and environmental harm that resulted from the accidental introduction of PBBs into the food system and environment in 1973, it is remarkable that other brominated flame retardants were able to largely escape scrutiny for nearly 25 years. Health concerns with current BFRs emerged only after Swedish studies demonstrated dramatic increases in PBDE levels in human breast milk. Dozens of studies since have shown how ubiquitous PBDEs have become in our bodies and in the environment.

A wide range of health concerns with BFRs are being researched in the scientific community and various regulatory bodies today. "Much of the concern with the BFRs is due to the fact that some of them appear to be persistent and bioaccumulative," reported Linda Birnbaum, a toxicologist and director of the U.S. Environmental Protection Agency's National Health and Environmental Effects Research Laboratory in Research Triangle Park, North Carolina. "Some of the BFRs—and it's important to stress that there are about 75 different BFRs and they are not all alike—are structurally similar to PCBs," she told *EBN*, "and may cause some similar effects."

Relative to one class of brominated flame retardants, PBDEs, toxicologist Thomas P. McDonald, M.P.H., Ph.D., with the California Office of Environmental Health Hazard Assessment, doesn't mince words. "All of the PBDEs are highly bioaccumulative," he told *EBN*. McDonald believes that children and adults pick up PBDEs through food (especially fish) and from direct indoor exposure through dust. Recent studies have found very high levels of PBDEs on window surfaces and in household dust. Infants ingest the compounds in breast milk and from household dust. A recent study of vacuum-cleaner dust from nine houses across the U.S. by the Environmental Working Group found PBDE levels ranging from 614 to 16,366 parts per billion, with an average concentration of 4,629 ppb. In a tenth house, where carpet padding had recently been removed, the PBDE concentration was over 41,000 ppb.

PBDEs tend to be especially prevalent in building dust and the environment because they are *additive* rather than *reactive* flame retardants—that is, they are held in place physically, rather than being chemically bound to the plastic molecules; over time, these additive compounds can escape. For an unknown reason, according to McDonald, a small portion of the population, about 5%, has very high levels of PBDEs compared with the rest of the population. "We don't

know why," he said, adding that this is raising serious concerns.

As for health impacts, McDonald says that there have been many studies on laboratory animals. Some PBDEs disrupt thyroid and estrogen hormones, which can cause developmental effects, such as permanent changes to the brain and to reproductive systems (including reduced sperm count in males and changes to ovarian cell structure in females). "Early life exposure [to PBDEs] is causing some permanent change that likely isn't desirable," he told *EBN*. The red flag, in McDonald's opinion, is that PBDE levels for that most contaminated 5% of the U.S. population (about 15 million people) are nearing concentrations that have been found to cause serious health effects in animal studies. "The current margin of safety is low," he said.

Early research pointed to the penta- and octa- forms of PBDEs as the primary compounds of concern. Indeed, the European Union and several states have taken action to ban these two forms of PBDE, and the only producer of these chemicals, Great Lakes Chemical Corporation, has agreed to cease production by the end of 2004. More recent research, however, shows that the far more common deca- form of PBDE, which had been thought to be too large and insoluble a molecule to be a health concern, degrades into lighter, more toxic brominated compounds that were previously associated with only the penta- and octa- forms of PBDE. Researcher Åke Bergman of Sweden's Stockholm University likens decaBDE to the pesticide DDT, which breaks down in the environment into a more persistent compound, DDE. It also appears that decaBDE can also have negative effects itself. A paper in the November 2003 issue of the journal *Toxicological Sciences* by Swedish researchers reported that mice fed decaBDE on their third day of life exhibited behavioral problems that worsened with age—results were similar to findings of previous research in which mice were exposed to pentaBDE.

Not surprisingly, the flame retardant industry claims that concerns about decaBDE are overblown. Anne Noonan, vice-president and general manager of Great Lakes Chemical Corporation, told *EBN* that there isn't any evidence that decaBDE is a health risk. "It's been proven to be clean," she stated. A voluntary phaseout of decaBDE is not going to happen, she said, because there are no viable alternatives.

Meanwhile, concerns about brominated flame retardants are extending beyond PBDEs. Hexabromocyclododecane (HBCD)—the third most widely used brominated flame retardant in the world and the BFR of choice for polystyrene foam—may actually be more prone to bioaccumulation than PBDEs. HBCD is just as likely to be toxic to humans, according to an October 9, 2003 article in the American Chemical Society's journal, *Environmental Science and Technology*. The Chemical Stakeholders Forum in the U.K. determined in March 2003 that HBCD is persistent, bioaccumulative, and toxic. The European Union is carrying out a risk assessment of HBCD, suspecting the compound of being an endocrine disruptor by impairing thyroid function. There are also growing concerns with TBBPA.

In addition to worries about persistence, bioaccumulation in living systems, and estrogenic effects of certain brominated flame retardants, there are also concerns about the formation of brominated dibenzofurans and dioxins in the event of accidental fire or during incineration at the end of product life. These compounds, like their more familiar chlorinated versions, are highly toxic and considered to be very serious environmental contaminants. A December 2000 German report, "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals," commissioned by the German Federal Environmental Agency, examined a wide range of environmental impacts of a dozen common flame retardants. The creation of dioxins and furans was raised as a concern with decaBDE and TBBPA but not with HBCD.

Table 2 summarizes health and environmental concerns with some of the more commonly used flame retardants, but this is by no means a comprehensive list of flame retardants.

### Regulatory Actions on Flame Retardants

A number of actions have been taken to phase out use of brominated flame retardants. As noted previously, PBB and tris-BP flame retardants were banned in the U.S. in the 1970s, along with PCBs. PCBs were banned through the 1976 Toxic Substances Control Act, which gives the EPA authority to track industrial chemicals, require testing of chemicals, and ban chemicals if toxicity concerns arise.

More recently, the European Union and two states in this country, California and Maine, have implemented bans of products containing more than 1% of pentaBDE or octaBDE, to take effect between the summer of 2004 (for certain

uses in Europe) and the beginning of 2008. These actions to ban the penta- and octa- forms of BDE are fairly inconsequential, however, because the sole producer of these chemicals has already agreed to cease production.

A more restrictive bill is being considered in New York that would include decaBDE in the PBDE restrictions and would set the threshold at *one-tenth* of 1% instead of 1%. The new Maine law also addresses decaBDE: "It is the intent of the Legislature to reduce the risk of the 'deca' mixture of [PBDEs] by implementing risk management measures or by prohibiting the sale of products containing more than 1% of the 'deca' mixture beginning January 1, 2008 if a safer, nationally available alternative is identified"; an actual ban of decaBDE in Maine, however, would require subsequent legislative action. A bill entered in the U.S. House of Representatives would require *labeling* of products containing decaBDE. In Europe, decaBDE is addressed in the RoHS Directive (Restriction of Hazardous Substances in Electrical and Electronic Equipment) but specifically exempted from the PBDE ban covering penta- and octa- forms, pending the outcome of a scientific risk assessment that will be completed by the end of 2004.

## Recommendations

Given the many concerns about PBDEs and other halogenated flame retardants, *EBN* recommends that architects, specifiers, and builders minimize or eliminate the use of all halogenated flame retardants in buildings they work on. The highest-priority products are those made with PBDEs, including decaBDE, but any halogenated flame retardant should be considered suspect until thorough life-cycle toxicity testing has been conducted and the compound is demonstrated to be safe.

Eliminating the use of halogenated flame retardants in the design, construction, and furnishing of buildings, however, is easier said than done. Not only are these flame retardants present in most polymer-based building materials and furnishings, but as *EBN* discovered, it is often very difficult to find out exactly which flame retardants are used in these products—this is not information that most manufacturers are interested in divulging. And current labeling regulations have thresholds or loopholes that allow manufacturers to avoid reporting flame-retardant content.

Working toward the goal of eliminating halogenated flame retardants must not result in elevated fire risk. If more flammable materials are used, changes such as fire-resistant construction detailing and sprinkler use must be incorporated to compensate for the reduced fire safety of materials and furnishings. Product substitutions also should not sacrifice energy performance or durability.

The checklist below provides some guidance in moving away from halogenated flame retardants.

Finally, there is a need for research on the potential health and environmental hazards posed by flame retardants of all types. Designers, specifiers, and product manufacturers need good information on risk in order to make informed product selections. We need to be able to objectively compare different classes of flame retardants as well as various compounds within a particular chemical group.

– Alex Wilson

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### For more information:

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[www.bsef-site.com](http://www.bsef-site.com)

European Flame Retardants Association  
Avenue E. Van Nieuwenhuysse, 4 Bte 2  
B-1160 Brussels, Belgium

32-2-676-7286

[www.cefic-efra.com](http://www.cefic-efra.com)

Environmental Working Group

1436 U Street NW, Suite 100

Washington, DC 20009

202-667-6982

[www.ewg.org](http://www.ewg.org)

Environmental Health Perspectives, a peer-reviewed journal with significant coverage of BFRs

Public Health Service, U.S. Department of Health and Human Services

Open-access: [www.ehponline.org](http://www.ehponline.org)

Brominated flame retardant manufacturers:

Great Lakes Chemical Corporation

[www.greatlakes.com](http://www.greatlakes.com)

Albemarle Corporation

[www.Albemarle.com](http://www.Albemarle.com)

Dead Sea Bromine Group

[www.dsbg.com](http://www.dsbg.com)

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### Checklist: Flame Retardants: A Checklist for Action

**Ask manufacturers about halogenated flame retardants in their products.** Even if products free from halogenated flame retardants cannot be obtained today, simply asking manufacturers or manufacturers' reps about these additives will raise awareness and lead to changes in the future.

**Avoid combustible materials where feasible.** Instead of using inherently flammable materials that have to be treated with flame retardants, such as foamed-plastic insulation, use inherently nonflammable materials, such as fiberglass or mineral wool insulation. (To avoid an energy penalty for such substitutions, thicker wall sections may be required.) Avoid foam cushioning in furniture in favor of mesh, as in some new "green" office chairs.

**Rely on separation of combustible materials to provide fire protection.** Combustible materials can be used with fairly low risk by providing adequate separation from occupied spaces or potential combustion sources.

**Install sprinklers in all buildings.** Full sprinklering should be provided in all occupied buildings, including single-family homes, to provide protection from fire.

**Where feasible and where there will not be energy penalties, avoid foam insulation.** Avoid foam insulation in most applications unless the manufacturer can provide assurance that halogenated flame retardants are not used. Most foam insulation today is made with halogenated flame retardants, though polyisocyanurate and spray polyurethane insulation is typically made with TCPP, which contains chlorine rather than bromine and is probably less of a health and environmental risk. Rigid fiberglass, rigid mineral-wool, and all cavity-fill insulation (fiberglass, mineral wool, and cellulose) is made without halogenated flame retardants.

**Do not use polyurethane foam carpet padding.** Soft polyurethane foam carpet padding is produced with pentaBDE or other brominated flame retardants. As the padding disintegrates, dust may become airborne or be ingested. This dust can be particularly dangerous to infants. In place of polyurethane padding, use more traditional materials, such as jute and horse-hair padding.

**Remove polyurethane foam insulation from beneath carpeting.** Polyurethane foam padding disintegrates over time, releasing PBDEs into the building. Removing this padding should be a moderately high priority. Use great care to minimize the release of dust into the building, wear a respirator, and clean up thoroughly with a HEPA vacuum.

**Specify office and household furniture that does not contain polyurethane foam padding.** A number of leading office furniture manufacturers, including Herman Miller, are trying to eliminate halogenated compounds from their products. The retailer IKEA has eliminated BFRs from all of its furniture.

**If polyurethane foam is used in furniture, specify foam with nonhalogenated flame retardants.** Unfortunately, it is very difficult to find out exactly which flame retardants are used in a particular product, so this may not be feasible. With large orders of office furniture, the specifier may wield enough influence to obtain this information from potential suppliers.

**Specify office equipment with metal cases rather than plastic.** Because most plastics are inherently flammable, flame retardants are commonly added. By switching to inherently flame-resistant materials, the need for flame retardants can be avoided. (This is the approach Apple Computer has taken in eliminating brominated flame retardants from all plastic components larger than 25 grams—substituting aluminum for plastic in computer casing, for example.)

**Specify halogen-free wire and cable.** Polyethylene and polypropylene insulated wire and cable that is produced using nonhalogenated flame retardants is available, though such materials may be difficult to find, and they may need to be installed in metal conduit to provide fire separation. The GreenSpec<sup>®</sup> Directory lists several such products. See EBN [Vol. 13, No. 3](#) for more on wire and cable.

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  3. Source: Bromine Science & Environmental Forum, 2001
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