INTRO
Biophysical Chemist Arlene Blum has immersed herself in evaluating the costs and benefits of use of and exposure to fire retardant chemicals. Her conclusion? Fire may not be the bigger hazard. Fire safety regulations born of good intentions have created a persistent biological threat. This article will provide data to help assess the costs and benefits of adding these chemicals to consumer products.

Chemical of Concern

The chemicals under the most scrutiny are man-made, polybrominated diphenyl ethers known collectively as PBDEs. Three different commercial formulations, known as Tetra-, Penta- and DecaBDE were used in consumer products in the US beginning in the 1970s. PBDEs are not chemically bound to the products they are used in and thus are prone to leaching into the environment, where they persist. Like other persistent organic toxins they have an affinity for fats. *(EPA factsheet)*

In the limited toxicity testing to date, OctaBDE and PentaBDE proved in animals to be detrimental to the neural and thyroid hormonal systems. It also acted as an endocrine disrupter. The Environmental Protection Agency (EPA) has categorized DecaBDE as a possible human carcinogen and more than 100 peer-reviewed publications characterize PBDEs as toxic to neural, reproductive and thyroid function in animal studies.

People encounter PBDEs in building materials, carpets, textiles, electronics, cars, mattresses, foam furniture, and high temperature plastics like those used for TVs and computers. DecaBDE is ubiquitous in buildings and vehicles. One of the major concerns with deca is that it may "debrominate," or break down, when exposed to ultraviolet radiation. Breakdown products include PentaBDE and OctaBDE.

When PBDEs are not used, (2, 3 - Dichloropropyl) Phosphate -- also known as TDCP or chlorinated Tris -- is among manufacturer's preferred flame retardants. Its toxicity famously led in the 1970s to the prohibition of its use in children's pajamas.

Consumer Goods: Electronics & Toys
The byproducts of degraded PBDEs have been identified in various plastic toys, figurines, dolls and toy vehicles. PBDEs are used in the hard plastic casing of electronics such as cell phones, computers and televisions. Since the 1970s the electronics industry has been one of the largest consumers of PBDEs. About 40 percent of PBDEs are used in the outer casings of computers, printers and televisions. (*Ecology center, 2007*)

PentaBDE and OctaBDE are generally no longer used. The largest volume of PBDEs used as a flame retardant has been DecaBDE, which is still in use and is still vigorously marketed by the bromine industry. Many computer manufacturers have eliminated DecaBDE from their products. Television manufacturers constitute 45–80 percent of all DecaBDE use in the US. (*Washington State Department of Ecology and Department of Health, Clean Production Action)*

During the product's lifespan PBDEs can degrade and outgas, but perhaps a greater concern is what happens after appliances have outlived their usefulness. Electronic waste accounts for 2 percent of America's trash in landfills but 70 percent of its toxic garbage. (Slade, Mother Jones, 2007)

Cars
Car interiors, especially when new, contain high levels of airborne PBDEs, despite a ban by the global automotive industry. In a Greek study published in 2008, air samples taken from 33 cars, including vehicles from 15 different European, Japanese, and U.S. manufacturers, "clearly indicat[ed] the presence of PentaBDE in car interiors." (*Mandalakis, 2008*) Vehicle components that contain deca are exposed to high UV levels and heat when parked in the sun, so it is not surprising that research conducted by the Ecology Center found that concentrations of Penta-, Octa- and DecaBDE were much higher in dust and window film samples from new model vehicles than from samples obtained in homes and offices. (*Ecology center*)

Furniture
Because of California's mandated furniture flammability standard, PentaBDE was added to furniture foam sold in the state for more than 20 years. Current estimates are that 40 percent or more of upholstered furniture sold nationally complies with the 1975 California standard known as TB 117. In most cases compliance means the addition of PBDE. In some cases, particularly in recent years, other chemicals such as TDCP (Tris) have been used. In a few cases it means furniture is constructed with naturally flame retardant materials.

Evidence of Danger from PBDEs

Human exposure of particular interest to breast cancer researchers
Studies published in 2008 indicate PBDEs can cause endocrine disruption in vitro, including one study that used a human breast cancer cell line *(Mercado-Feliciano, 2008).* Internal exposure "may significantly contribute to the overall risk of endocrine disruption," according to a Dutch study published in the February, 2008 issue of Molecular Nutrition and Food Research. And a study of breast fatty tissue samples from 23 California women found average PBDEs at "the highest human levels reported to date." (*She, 2002*)

Food animal exposure
In the fall of 2002, researchers from the Environmental Working Group collected 22 fish from six of the most commonly eaten species at 10 locations around San Francisco Bay. Every sample contained seven different PBDEs, and in levels much higher than in fish from Europe, Japan and other parts of the U.S. Compared to archived samples from 1997, levels had more than doubled in halibut and more than tripled in striped bass (*EWG, 2002*)

Persistence of exposure
A California EPA researcher has observed that the levels found in women's breast milk are not only high, but persistent. (*Hooper, 2007*) The California EPA also looked at banked blood samples collected in the 1960s from San Francisco Bay Area women and found the level of PBDEs was below measurable, however, when the same researchers looked at levels from 1997-2002, they found PBDE levels in the blood of San Francisco Bay Area women were 3 - 10 times higher than Europeans'. "Increasing body burdens," they wrote, "pose a potential public health threat to future generations." *(Petreas, 2003)*

As consumer products are used and after they are discarded, PBDEs are released into the environment where they can bioaccumulate in wildlife and food animals. The EPA acknowledges no "treatment" is currently available to remediate them from the environment. (*EPA factsheet*)

Means of exposure
With the exception of breast milk, food is not considered to be a major source of human PBDE contamination. Rather, many researchers suspect that contaminated dust conveys PBDEs. Samples collected from household vacuum cleaner bags in Davis, California, were all highly contaminated. (*Hwang, 2008*) In 2006 staff from a California environmental CBO, with support from the Silent Spring Institute, collected air and dust samples both inside and outside 40 homes in Richmond, CA and 10 homes in Bolinas, CA. Levels of PBDEs in the house dust were substantially higher than previously reported in the United Kingdom, Germany, Ottawa, Canada; Cape Cod, MA; Boston or Washington D.C. (*Zota; unpublished abstract presented October 15, 2007 at the 17th Annual Meeting of the International Society of Exposure Analysis*)

How that dust gets into human tissues has been unclear, but researchers recently hypothesized that eating oily finger foods such as chips with unwashed hands could result in inadvertently consuming PBDEs. The toxins may also be absorbed directly into the body via the skin. (*Stapleton, 2008*) Young children, and in particular, toddlers, are among those most likely to receive high exposure because they're in contact with house dust through floor activities and hand-to-mouth behaviors. (*Fisher, 2006*)

Regulatory Environment

Europe
Regulation of chemicals in Europe is substantially different than in the US. As of June 1, 2007, the REACH system is being phased in, placing greater responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. The acronym stands for Registration, Evaluation, Authorization and Restriction of Chemical substances. (EU documents) The European Union prohibited use of pentaBDE and octaBDE in 2003. (EU directive 2003/11/EC) After years of vacillation, on April 1st, 2008 the European Court appears to have ruled definitively that DecaBDE must be banned in all electronic products.

US
No federal standards or guidelines have been set for PBDEs. (*EPA factsheet*) (Manufacture of PentaBDE and OctaBDE was voluntarily ended on December 31, 2004).

A 2007 federal open flame standard for mattresses provided for the nation the same level of regulation previously in effect in California. Often called the "candle" standard, it is designed to give consumers more time to escape a fire. The standard for mattresses does not address ignition from cigarettes because that specific protection would be redundant. A mandatory federal standard on cigarette ignition of mattresses, 16 CFR Part 1632, has been in place for more than 30 years. (Furniture Today)

In December 2007 the Consumer Product Safety Commission (CPSC) proposed a national flammability standard for furniture that can be met without fire retardant chemicals in foam. The

proposed standard would require fabric to be fire resistant instead of the foam inside. The regulations would, however, still allow the use of known toxic chemicals on foam, including TDCP. (*Enviroblog, EWG*)

California

In 1975 California's Bureau of Home Furnishings and Thermal Insulation (BHFTI) issued Upholstered Furniture Flammability Standard Technical Bulletin 117 (TB117) which requires polyurethane foam in furniture foam sold in California to withstand a 12-second exposure to a small open flame. To meet that requirement, PentaBDE was added to foam in amounts up to 10 percent of the weight of the foam from 1980 to 2004. No flammability requirement was enforced for fabric.

Citing environmental concerns, in 2003 California AB 302 sponsored by Assemblywoman Wilma Chan banned Penta- and OctaPBDEs making California the first state to prohibit their use. DecaPBDE was not prohibited. The state maintains stringent flammability requirements for furniture and in 2007 BHFTI proposed Technical Bulletin TB 604 that would extend flammability requirements to bed clothing (quilts, comforters, and pillows).

In 2008 Assemblyman Mark Leno introduced AB760. Echoing the European Union's REACH, the bill would have introduced a state process to assess the safety of fire retardant chemicals for the purpose of guiding manufacturers and the public toward safer alternatives. The bill passed the Assembly but was defeated in a Senate vote.

Other states

- Washington and Maine have enacted partial restrictions on the use of DecaPBDE
- PentaBDE and OctaBDE (and articles containing them) have been prohibited in Illinois, Hawaii, Maine, Maryland, Michigan, Montana, New York, Oregon, Rhode Island and Minnesota. The Minnesota law also requires a study of Deca and safer alternatives and encourages the state to procure products that do not contain PBDEs

Quantifying Fire Danger

How great is the loss attributable to fire? In 2006 (the last year for which there are data available) house fires caused the deaths of 2,580 Americans (other than firefighters) and $6.8 billion in direct damage. Deaths by fire in the US are trending down: the National Fire Protection Association compared fire deaths during the period 1995-1999 with a prior five year period (1980-1984) and found rates were down 32 percent in California, 40 percent in New York and 39 percent in Illinois. (*NFPA*)

Fire requires spark or ignition, fuel, heat and oxygen. Therefore at least four opportunities present for suppression. Among fire-safety professionals, redundancy is preferred, giving rise to multiple streams of fire-safety efforts including safer consumer goods, public education and building regulations. One apparently under-realized opportunity is the use of smoke detectors: almost two-thirds of reported home fire deaths resulted from fires in homes with no smoke alarms or no working smoke alarms. (*NFPA*)

There is some value in fire-retarding the fuel, but when it comes to saving lives, Blum's research concludes that reducing ignition sources is more effective than fire-retarding the fuel. This is

especially true with regard to Reduced Ignition Propensity (or "firesafe") cigarettes. While cooking causes a greater number of residential fires it is the fires caused by cigarettes that are most likely to be fatal. (*NFPA*) Firesafe cigarettes may reduce fire deaths by 50 to 66 percent.

As of Aug 1, 2008, 82 percent of Americans are protected by state firesafe cigarette laws (*coalition for fire-safe cigarettes, 2008*). Federal regulation is absent because tobacco remains exempted from CPSC jurisdiction. Further reductions in cigarette ignition will follow two events: industry compliance and a continued decrease in the numbers of smokers.

- In 2008 RJ Reynolds Tobacco Co, whose products constitute 35 percent of the market, announced it will phase in firesafe cigarettes for all its brands, with full distribution to be completed within two years. (*coalition for fire-safe cigarettes, 2008*)
- Cigarette use has dramatically declined in the US since 1964 and continues to drop, particularly where smoking cessation public health efforts are stronger. (*American Cancer Society, 2008)*

Cost/Benefit analysis of chemical flame retardants

Of course most beds, couches and televisions never catch fire. But until its ban 20 million pounds of PentaBDE was used each year in the US, primarily to comply with TB 117. Now that PentaBDE has been phased out manufacturers are using other flame retardants. The CPSC estimates an annual increase in cancer of up to 1,200 cases if Tris were to be added to furniture to meet an open flame standard. Nationally, in 2003 there were an estimated 20 deaths in which upholstered furniture was the first item ignited by an open flame. An additional 220 such upholstered furniture fire deaths were started by an unknown source. (*NFPA*)

Using a complex analysis, Brian Roach of Tufts University Global Development and Environment Institute calculated the potential benefit of the CPSC's proposed national flammability standard based on the assumption that many manufacturers would replace PBDEs with TDCP. "Health risks associated with TDCP far outweigh any potential benefits of the flammability standard," he wrote. (*Brian Roach, Global Development and Environment Institute, Nov 2007 memo to Arlene Blum)* Because of the paucity of research and because the health dangers of this class of chemicals become apparent after many years, it is difficult to quantify the potential disease burden of PBDEs. Roach, for example, calculated a 20-year delay into his TDCP analysis.

In 2007 the Consumer's Union wrote "There are effective alternatives to PBDEs, and manufacturers here and in Europe are beginning to turn to them as federal and state governments initiate phase-outs or bans of certain PBDE compounds." A report by the Danish EPA confirms there are alternatives: "This study has not identified any application of DecaBDE in electrical and electronic equipment for which substitution is not possible, from the scientific or technical point of view." (Danish EPA, 2007)

Blum has been leading seminars titled "The Fire Retardant Dilemma" since 2007. As a result of her research and the knowledge accumulated in the seminars, she offers three policy recommendations:

- Fire retardant chemicals and materials must be shown safe for human health and environment before use.
- Research and Development money is needed to design and produce non-toxic fire retardants and materials using green chemistry.

- A moratorium should be placed on new flammability regulations until fire retardant materials or alternative strategies have been shown to be safe.

Existing, less toxic methods for reducing US losses due to fire are underutilized. And although fire remains a risk to life, health and property, it may not be a bigger public health hazard than flame retardant chemicals. Unfortunately it may take a generation for that to be fully understood.

Chemical of Concern

"Like other persistent organic toxins they have an affinity for fats"*Emerging Contaminants – Polybrominated Diphenyl Ethers (PBDE) and Polybrominated Biphenyls (PBB), EPA publication # 505-F-07-007, 2008*

Consumer Goods: Electronics & Toys
"About 40 percent of PBDEs are used in the outer casings of computers, printers and televisions." *HealthyToys.org, a project of the Ecology Center*

"Television manufacturers constitute 45–80 percent of all DecaBDE use in the US" *Clean Production Action, 2008. cleanproduction.org*

"Electronic waste accounts for 2 percent of America's trash in landfills but 70 percent of its toxic garbage*." Ten thousand songs in your pocket. Ten thousand years in a landfill. Giles Slade, Mother Jones, March/April 2007*

Cars
"…air samples taken from 33 cars…clearly indicat[ed] the presence of PentaBDE in car interiors." *Emerging Contaminants in Car Interiors: Evaluating the Impact of Airborne PBDEs and PBDD/Fs; Environmental Science Technology, 42 (17), 6431–6436, 2008*

"…higher in dust and window film samples from new model vehicles than from samples obtained in homes and offices" *HealthyCar.org, a project of the Ecology Center*

Evidence of Danger from PBDEs

Human exposure of particular interest to breast cancer researchers
"PBDEs can cause endocrine disruption in vitro, including one study that used a human breast cancer cell line" *The Polybrominated Diphenyl Ether Mixture DE-71 Is Mildly Estrogenic, Mercado-Feliciano, et al, Environmental Health Perspectives, 2008*

"…samples from 23 California women found average PBDEs at "the highest human levels reported to date" She et al, *PBDEs in the San Francisco Bay Area: measurements in harbor seal blubber and human breast adipose tissue, Chemosphere, 2002*

Food animal exposure
"…levels had more than doubled in halibut and more than tripled in striped bass*" Tainted Catch: Brominated fire retardants (PBDEs) found in San Francisco Bay fish: PBDE's in 2002 Fish, Environmental Working Group, 2003*

Persistence of exposure
"…levels found in women's breast milk are not only high, but persistent." *Depuration of Polybrominated Diphenyl Ethers (PBDEs) and Polychlorinated Biphenyls (PCBs) in Breast Milk from California First-Time Mothers (Primiparae), Hooper, et al, Environmental Health Perspectives, 2007*

"…a potential public health threat to future generations*." High Body Burdens of 2,2´,4,4´-Tetrabromodiphenyl Ether (BDE-47) in California Women, Petreas, et al, 2003, Environmental Health Perspectives*

"…no "treatment" is currently available to remediate them from the environment" *EPA publication # 505-F-07-007 April 2008: "Emerging Contaminants – Polybrominated Diphenyl Ethers (PBDE) and Polybrominated Biphenyls (PBB)*

Means of exposure
"Samples… were all highly contaminated" *Occurrence of endocrine-disrupting chemicals in indoor dust, Hwang et al, The Science of the Total Environment, 2008*

"Levels of PBDEs in the house dust were substantially higher than previously reported." (*Zota et al; unpublished abstract presented October 15, 2007 at the 17th Annual Meeting of the International Society of Exposure Analysis*)

"…toxins may also be absorbed directly into the body via the skin." *Measurement of Polybrominated Diphenyl Ethers on Hand Wipes: Estimating Exposure from Hand-to-Mouth Contact, Stapleton et al, Environmental Science Technology, 2008*

"…they're in contact with house dust through floor activities and hand-to-mouth behaviors" *Children Show Highest Levels of Polybrominated Diphenyl Ethers in a California Family of Four: A Case Study, Fischer et al, Environmental Health Perspectives, 2006*

Regulatory Environment

Europe
"As of June 1, 2007, the REACH system is being phased in…"*europa.eu*

"The European Union prohibited use of pentaBDE and octaBDE in 2003" *Directive 2003/11/EC of the European Parliament and of the Council, 2003*

US

"No federal standards or guidelines have been set for PBDEs" *Emerging Contaminants – Polybrominated Diphenyl Ethers (PBDE) and Polybrominated Biphenyls (PBB), EPA publication # 505-F-07-007, 2008*

"A mandatory federal standard on cigarette ignition of mattresses, 16 CFR Part 1632, has been in place for more than 30 years." *Basic facts about the new federal mattress FR standard, David Perry, Furniture Today, July 2, 2007*

"…regulations would, however, still allow the use of known toxic chemicals on foam, including TDCP." *EWG applauds CPSC's move toward safer furniture, Enviroblog.org, Environmental Working Group, 2008*

Quantifying Fire Danger

"…rates were down 32 percent in California, 40 percent in New York and 39 percent in Illinois." *National Fire Protection Association, NFPA.org*

"…almost two-thirds of reported home fire deaths resulted from fires in homes with no smoke alarms or no working smoke alarms" *National Fire Protection Association, NFPA.org*

"…it is the fires caused by cigarettes that are most likely to be fatal." *National Fire Protection Association, NFPA.org*

"RJ Reynolds Tobacco…will phase in firesafe cigarettes for all its brands…" *Blog, Coalition for Firesafe Cigarettes, firesafecigarettes.org*

"Cigarette use has dramatically declined in the US since 1964 and continues to drop…" *American Cancer Society, Cancer Prevention & Early Detection Facts & Figures 2008*

Cost/Benefit analysis of chemical flame retardants

"An additional 220 such upholstered furniture fire deaths were started by an unknown source" *National Fire Protection Association, NFPA.org*

"This study has not identified any application of DecaBDE in electrical and electronic equipment for which substitution is not possible" *Deca-BDE and Alternatives in Electrical and Electronic Equipment, Danish Ministry of the Environment, Project no. 1141, 2007*