

**Report on Alternatives to the Flame Retardant DecaBDE:  
Evaluation of Toxicity, Availability, Affordability, and Fire  
Safety Issues**

**A Report to the Governor and the General Assembly**

**Illinois Environmental Protection Agency**

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## EXECUTIVE SUMMARY AND RECOMMENDATIONS

In 2006, the Illinois Environmental Protection Agency (Agency) issued *A Report to the General Assembly and the Governor in Response to Public Act 94-100, "DecaBDE Study: A Review of Available Scientific Research."* This report presented the Agency's findings on five issues raised in Public Act 94-100 regarding the flame retardant chemical Decabromodiphenyl ether (DecaBDE). The Agency found that DecaBDE is bioaccumulating in the environment and that levels are increasing in some samples. We also found that humans are exposed to DecaBDE, mainly from the diet, workplace, and home. We were not able to fully determine what health effects could result from exposure, whether DecaBDE breaks down into more harmful chemicals, and if safer alternatives are available that still maintain fire safety, due to uncertainties from insufficient data. Regarding these last three issues, we were able to report that liver, thyroid, reproductive/developmental, and neurological effects are the most important effects seen in animal studies with DecaBDE and other polybrominated diphenyl ethers (PBDEs); that DecaBDE breaks down to other chemicals under some conditions; and that effective alternatives exist for most DecaBDE uses but their toxicity databases contain gaps.

In response to this report, Governor Blagojevich sent a letter to the Agency requesting a follow-up study to answer the critical issues remaining from the 2006 report, and to determine whether safer and affordable alternatives to DecaBDE are available that still meet fire protection standards. The following provides the Agency's findings and recommendations regarding potential replacements for DecaBDE's uses.

### FINDINGS

In this report, we have updated significant issues that were found to have insufficient information in our 2006 report, reviewed the toxicity data for selected alternatives to DecaBDE, and assessed the affordability and availability of DecaBDE alternatives. These topics are summarized as follows.

**Update of significant issues** – In our 2006 report, we were not able to fully answer whether DecaBDE breaks down into more harmful chemicals, what health effects could result from exposure to DecaBDE, and whether DecaBDE alternatives were available that are safer than DecaBDE and still meet fire protection standards. Since issuing the 2006 report we have reviewed additional information regarding these issues, and now find:

- Evidence continues to accumulate that DecaBDE can be broken down by light and microbial organisms under certain conditions, and we are now confident that animals can metabolize it into a variety of breakdown products; there is still uncertainty about whether the breakdown by light and microbes occurs under conditions normally occurring in the environment (temperature, moisture levels, etc.) and which of the many breakdown products might be the most abundant and most important toxicologically.
- Regarding the health effects of the PBDEs, we now have additional evidence that DecaBDE, certain DecaBDE breakdown products, and other PBDEs can cause thyroid, reproductive/developmental, and neurological effects; although there is still uncertainty

about DecaBDE's role in these effects, our level of uncertainty has decreased from the 2006 report, and further justifies an in-depth evaluation of potential alternative flame retardants for products still using DecaBDE.

**Toxicity of DecaBDE alternatives** – There are a number of ways to flame-retard for products that do not require chemicals and for which toxicity is not a concern. Examples include redesigning products to be less fire-prone, and the use of inherently fire-resistant fibers and light-weight metals. For a description of such DecaBDE alternatives, see Section 6 of the 2006 DecaBDE report.

With respect to chemical alternatives, we evaluated those which are currently in widespread use or are expected to be in the future. We developed a scoring approach that ranked the health and environmental effects data for chemical alternatives to DecaBDE as being of high, moderate, low, or no concern, and then grouped them into “bins” of overall level of concern: Potentially Unproblematic, Potentially Problematic, Insufficient Data, and Not Recommended. There is insufficient toxicity data available for the alternatives to say with certainty that they pose little or no risk and are therefore “safe” to use as flame retardants. However, some of the chemical alternatives do appear to be safer than DecaBDE.

**Affordability and availability of DecaBDE alternatives** – In order to gauge the relative affordability and availability of DecaBDE alternatives, the Agency undertook a widespread review of information relevant to these issues including direct contact with several electronics and transportation industry trade groups/associations, product manufacturers, and large retailers. Based on our evaluations, it appears that there are only a few current DecaBDE uses for which the alternatives still have affordability and/or availability concerns, while there are many uses/products for which a phase-out of DecaBDE is substantially complete or is in progress. Our findings include:

- Consumer electronics – No significant affordability issues, with phase-out of DecaBDE substantially complete; some manufacturers just beginning phase-outs may need additional time to complete fire protection tests and product re-design studies.
- Other electrical applications and electronic products (particularly wiring, cable, and electronic assemblies) – No significant affordability issues, with phase-out of DecaBDE substantially complete; some additional, minimal product performance testing may still be required to complete the transition.
- Medical devices – Moderate affordability issues, extensive product testing still to be accomplished before phase-out possible.
- Textiles and foams – Affordability issues remain, but only for use in the transportation sectors; many affordable options are available to replace DecaBDE uses in furniture, mattresses, draperies and other textiles applications.
- Transportation – Significant affordability issues, related to performance and fire protection standards required by regulations and manufacturer's specifications; significant time still needed to complete product performance and fire safety testing of plastics, electrical wiring, electronics, fuel systems and upholstery.

## RECOMMENDATIONS

From the findings discussed above, the Agency now believes there is reason for concern regarding the continued use of DecaBDE in many products. This concern is based on:

- the widespread occurrence of DecaBDE in the environment
- the uncertainty surrounding the ultimate fate of DecaBDE in the environment and in organisms, and
- the growing database of toxic effects attributed to DecaBDE, its metabolites, and other PBDEs.

Because of these concerns and the fact that a significant number of alternatives are affordable, available and have better toxicity rankings than DecaBDE, the Agency recommends that the Governor support a managed state-level phase-out of several DecaBDE's uses. This approach should include the following elements:

- Establish a realistic target, possibly by year-end 2010, for the phase-out of DecaBDE, focusing on uses and industrial applications where there are available, affordable and potentially less toxic alternatives. Focus initially on DecaBDE used in electronics and textiles (excluding textiles used in the transportation sectors).
- Provide exemptions/extensions for those uses where alternatives are demonstrated not to be feasible.
- The managed phase-out could be accomplished through voluntary actions, negotiations, rules, and/or legislation.

In addition, the State should:

- Continue discussions with manufacturers, industry associations, environmental advocates, etc., to evaluate additional information pertaining to fire safety/flame retardants.
- Explore the creation of a clearinghouse among state environmental agencies as a central repository for information regarding flame retardants that can be made available to interested parties.
- Modify state purchasing decisions to favor purchase of DecaBDE-free products.

## 1.0 INTRODUCTION

In January 2006 the Illinois Environmental Protection Agency issued *A Report to the General Assembly and the Governor in Response to Public Act 94-100, "DecaBDE Study: A Review of Available Scientific Research."* This report presented the Agency's findings regarding five issues posed by the Legislature concerning the flame retardant chemical Decabromodiphenyl ether (DecaBDE):

- Whether DecaBDE is bioaccumulating in the environment, and if so, whether the levels of DecaBDE are increasing, decreasing, or staying the same;
- How humans are exposed to DecaBDE;
- What health effects could result from exposure to DecaBDE, and are current levels of exposure at levels that could produce these effects;
- Whether DecaBDE breaks down into more harmful chemicals that could damage public health; and
- Whether effective flame retardants are available for DecaBDE uses, and whether the use of available alternatives reduces health risks while still maintaining an adequate level of flame retardant performance.

In brief, the Agency found that DecaBDE is bioaccumulating and levels are increasing in some types of samples; that humans are exposed mainly from the diet, work place, and home; that liver, thyroid, reproductive/developmental, and neurological effects are the most important effects seen in animal studies, and human exposures may be in the range of doses causing some of these effects; that DecaBDE breaks down to other chemicals under some conditions; and that effective alternatives exist for most DecaBDE uses. The Executive Summary from the Agency's 2006 report, included as Attachment A of this report, contains a fuller description of the Agency's findings.

The Agency also noted that some serious deficiencies regarding DecaBDE were found during its review: there is uncertainty whether some of the health effects seen in laboratory animals are relevant to human health risk; there are important gaps in the toxicological database for DecaBDE; there is uncertainty whether break down to other chemicals occurs under environmentally relevant conditions and to what extent the DecaBDE molecule is broken down; and there are important gaps in the toxicological databases for many of the potential alternative flame retardants. The Agency noted that on-going or planned research might provide information that could remedy some of these deficiencies in the near future.

In a March 3, 2006 letter to Director Scott, Governor Blagojevich thanked the Agency for its report, noted that uncertainty about the health effects from DecaBDE exposure is cause for concern, and expressed encouragement that safer, effective alternatives to DecaBDE may exist that still meet fire protection standards. Therefore, Governor Blagojevich instructed the Agency to conduct a follow-up study to answer critical questions that remain about the environmental and health effects of DecaBDE and to determine whether safer alternatives are available. If the study finds that alternatives that meet fire protection standards are available, affordable, and less toxic, then the Agency should develop rules that require the use of these alternatives. A copy of Governor Blagojevich's letter is included as Attachment B.

This report is the Agency's response to Governor Blagojevich's request. In addition to this introductory section, we present background information on flame retardants, including DecaBDE and potential alternatives (Section 2), the findings of our follow-up research into the significant issues identified in the 2006 report and our evaluation of potential alternatives (Section 3), and our recommendations for possible future actions and approaches regarding potential alternatives (Section 4).



## 2.0 BACKGROUND INFORMATION

Chemical flame retardants are added to many materials and products to prevent or suppress ignition or to limit the spread of fire once ignition occurs. They have been credited with saving many lives and preventing injuries and loss of property as a result of mandated or voluntary use. There are hundreds of flame retardants available today, and more are being developed for specific uses. A wide variety of chemicals and chemical families are employed as flame retardants, including inorganic chemicals based on the elements phosphorus, aluminum, magnesium, zinc, and antimony, and organic chemicals based on bromine and/or chlorine (organohalogenes), phosphorus (organophosphates), and nitrogen. Products containing bromine comprise a significant portion of the flame retardant market due to this element's effectiveness at suppressing ignition and stopping the spread of flame, and relatively low cost.

### 2.1 The Polybrominated Diphenyl Ethers

The polybrominated diphenyl ethers (PBDEs) are one of the main classes of brominated flame retardants. There are theoretically 209 individual brominated diphenyl ethers (called congeners), differing in the number of bromine atoms (1 to 10) attached to the diphenyl ether "backbone" and in the positions of attachment of the bromines to the backbone. The only uses of the PBDEs are as flame retardants, and they have been produced primarily in three technical formulations, PentaBDE, OctaBDE, and DecaBDE, under a variety of trade names. The Penta-, Octa-, and DecaBDE formulations have an average of five, eight, and ten bromine atoms attached to the diphenyl ether molecule, although each product is a mixture of several closely related congeners. Information about these formulations is listed in Table 1. To avoid confusion, the remainder of this report will use capital letters when referring to the commercial PBDE formulations PentaBDE, OctaBDE, and DecaBDE; lower case letters for the general classes of congeners having the same number of bromine atoms but different points of attachment to the diphenyl ether backbone (monoBDE through decaBDE); and individual congeners will be identified by their accepted numbering system (for example, BDE-47 is 2,2',4,4'-tetrabromodiphenyl ether, and BDE-209 is decabromodiphenyl ether).

Table 1. Representative Levels of Brominated Diphenyl Ether Congeners Found in Polybrominated Diphenyl Ether Formulations (%).<sup>(a)</sup>

Formulation	Congener Percent							
	Tri-BDE	Tetra-BDE	Penta-BDE	Hexa-BDE	Hepta-BDE	Octa-BDE	Nona-BDE	Deca-BDE
PentaBDE	<1	24-38	50-60	4-8				
OctaBDE				10-12	43-44	31-35	10-11	<1
DecaBDE						Trace	<3	97-98

(a) International Programme on Chemical Safety, World Health Organization, "Environmental Health Criteria 162:Brominated Diphenyl Ethers", [www.inchem.org](http://www.inchem.org) viewed December 8, 2006.

The PBDE formulations have been used in a wide variety of products, including many types of plastics (often as housings for and components of electronic equipment), wires/cables, textiles, packaging materials, furniture, and upholstery. Typically, the PBDE formulation is added to the product or material in the range of 5-30% by weight. DecaBDE has been the most widely used of the three formulations, both in the United States and worldwide. Recent production of DecaBDE has exceeded 60,000 metric tons worldwide, and over 40% of the use of DecaBDE occurs in North America. Because of this widespread use the PBDEs have been detected in soil, water, sediments, air, and animals and humans world-wide. This widespread occurrence, and some of the reported toxic effects from laboratory studies of the PBDEs, has caused concerns about potential human and environmental health effects from exposure to the PBDEs. These concerns have resulted in the banning/voluntary withdrawal of the commercial Penta- and OctaBDE formulations, and calls for banning the DecaBDE formulation by several jurisdictions. However, in light of the proven benefits from flame retarding products with DecaBDE, if DecaBDE is banned it is imperative that any alternatives to DecaBDE's uses continue to provide effective levels of flame retardant performance.

## **2.2 Fire Safety Issues**

There are almost 400,000 residential fires each year, which lead on average to 4,300 deaths and 27,000 injuries, and about \$10 billion in property losses. Thus, in our review of the many potential alternatives to DecaBDE we paid close attention to the level of flame retardant performance provided by the alternatives. We have found that the numerous state, federal, and voluntary fire safety standards have driven the industries that use DecaBDE to provide a high level of flame retardant performance. Further, it appears that even in cases where flame retarding is not mandated manufacturers often flame-proof their products due to market pressure and brand image concerns. Thus, we are confident that potential DecaBDE alternatives will be used in a manner that provides flame retardant performance that meets or exceeds all mandated fire safety standards and regulations. A fuller discussion of fire safety issues as they relate to potential DecaBDE alternatives is presented in Appendix I.

## **2.3 Summary of Alternatives Section from 2006 Report**

This section provides a summary of the Agency's findings regarding DecaBDE alternatives in the 2006 report, in response to the following questions:

- Are there effective flame retardants available for current uses of DecaBDE;
- Will the use of available alternatives reduce health risks while still maintaining an adequate level of flame retardant performance.

We found that there are three general flame retardant alternatives to using PBDEs:

- Substituting non-brominated chemical additives
- Substituting product materials that don't require PBDEs
- Changing design and construction of products so they are inherently less flammable

Our research showed that DecaBDE is used in two primary arenas, electronics enclosures and textiles. We focused on these uses because the electronics and textile applications accounted for nearly 80% and 10-20%, respectively, of DecaBDE used. The main electronics application was in high impact polystyrene (HIPS) enclosures used in the rear of television sets, while there were many uses in textiles, including mattresses, drapery, commercial upholstered furniture, and transportation, particularly the automotive and airline industries.

At that time, we found no cost effective non-halogen flame retardants for electronic enclosures, but there were a number of phosphorus-based flame retardants that could serve as effective non-halogen substitutes in HIPS blends and other resin systems. However, they were more costly than DecaBDE HIPS systems and their adoption in the US was found to be limited at that time. Three substitute resin possibilities were identified:

- Blends of polycarbonate and acrylonitrile-butadiene-styrene (PC/ABS)
- Polycarbonate (PC)
- Blends of HIPS and polycarbonate oxide (HIPS/PPO)

The following organic phosphorus compounds were found to be used in varying extent with PC/ABS and HIPS/PPO resins:

- Triphenyl phosphate (TTP)
- Resorcinol bis(diphenylphosphate) (RDP)
- Bisphenol A diphosphate (BAPP)
- Bisphenol A bis diphenyl phosphate (BDP)

In general, few human health concerns were found with these compounds. However, more data on human and environmental toxicity of the compounds was needed.

Unlike electronics enclosures, DecaBDE substitution is complicated with textiles given the possible substitution approaches. Strategies for substituting DecaBDE in textiles included the redesign of products to reduce their fuel load by eliminating the use of foam (for example, in office chairs). Other strategies included the application of other chemical flame retardants, the incorporation of barrier layers in products, and utilizing inherently fire-resistant fabrics.

Natural fibers are easier to chemically flame retard than synthetic, and there are several chemically applied non-halogen DecaBDE substitutes available for natural cellulose fibers such as cotton, wool, rayon, and linen. They include:

- Ammonium polyphosphates
- Dimethylphosphono (N-methylol) propionamide
- Phosphonic acids such as (3-{[hydroxymethyl]amino}-3oxopropyl)-dimethyl ester
- Tetrakis (hydroxymethyl) phosphonium urea ammonium salt

Some DecaBDE substitutes exist for synthetics, but their water solubility results in limited durability as they “wash out” during laundering. Blending natural and synthetic fibers is one approach since the natural fibers are more effectively flame retarded. Some fire resistant fibers

require no added flame retardant, and these inherently fire resistant fibers can be used as DecaBDE substitutes for high durability synthetic fibers. Unfortunately, we were able to find very little information about the costs related to DecaBDE substitutes/alternatives.

Likewise, we found at that time that the human and ecological toxicity risks associated with the DecaBDE substitutes were not well known, despite their widespread, and in some cases, long term use. For example, the four organic phosphorus compounds listed above as potential alternatives for electronics enclosures appeared to suffer some of the same database deficiencies as DecaBDE regarding reproductive/developmental and neurological effects. Nevertheless, in general the phosphorus-based alternatives appeared to have fewer health and environmental concerns than the PBDEs, since they did not appear to be bioaccumulative or break down into toxic and bioaccumulative chemicals.

In summary, the Agency's review of DecaBDE alternatives permitted us to respond, tentatively, to the two questions in the affirmative. We found that effective flame retardant alternatives to most DecaBDE uses exist, although the cost-effectiveness of these alternatives was beyond the Agency's expertise to determine, and use of the alternatives would likely reduce risks while maintaining an adequate level of flame retardant performance. Further research was found to be needed to better evaluate the potential health and environmental consequences of many of the major DecaBDE alternatives.

## **2.4 Scope of this Report to the Governor**

The primary focus of this report will be an evaluation of potential alternatives to DecaBDE. The Governor's letter to the Agency also includes a request to follow-up on the critical questions that remain from the 2006 report regarding environmental and health effects of DecaBDE. Thus, we provide a discussion of new findings from studies and reports concerning the breakdown of DecaBDE and the health effects of DecaBDE and other PBDEs in Section 3 to update these issues.

The Governor's letter asks the Agency to determine if there are alternatives that are available, affordable, and less toxic than DecaBDE, while still allowing products to meet fire safety standards. As discussed above, we believe that DecaBDE alternatives will meet fire safety standards; Section 3 also contains evaluations of whether potential alternatives are available, affordable, and less toxic than DecaBDE. Section 4 concludes this report with recommendations for future actions that could be taken regarding DecaBDE and alternatives.

In order that this report does not become unwieldy, we have decided not to attempt to evaluate a large number of the potential alternatives to DecaBDE's uses. Instead, we have focused primarily on those alternatives that are already being used in commercial products, and also on some that appear to be most promising as replacements for certain of DecaBDE's uses. As a policy decision, we will not evaluate alternatives containing the halogens chlorine and bromine, even though some of these chemicals would be available, affordable, and less toxic than DecaBDE in our evaluation system. This is done out of concern that these alternatives can generate highly toxic halogenated dioxins and furans if products flame-retarded by such chemicals are involved in a fire or are incinerated at end-of-life disposal.

## Section 2.5 State Legislation

In the United States, several laws have been enacted and legislation introduced relating to PBDEs in at least 13 states including California, Connecticut, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, New York, Oregon, Rhode Island, and Washington. These legislative initiatives initially addressed Penta- and OctaBDE; however, many of the legislative initiatives also discuss potential use of DecaBDE alternatives. As of January, 2007 most of the DecaBDE related legislation has not been passed and is still under discussion by the States. It is worth noting that special provision addressing affordability issues have been included in several proposed state laws. These include:

- Oregon and Washington proposed statutes discuss exemptions for transportation, used products, or replacement parts for products introduced into commerce before the effective date of the ban.
- Washington, Maine, and Connecticut proposed statutes restrict uses of DecaBDE by January 1, 2010.
- Proposed legislation in Washington requires state agencies to lead by example and purchase PBDE-free products.
- Proposed legislation in Connecticut requires manufacturers to provide safety data on alternatives to PBDE.

## 3.0 FINDINGS

This section presents our findings in response to Governor Blagojevich's letter instructing the Agency to follow up on critical issues identified in the Agency's 2006 report on DecaBDE and to determine whether safer and affordable alternatives to DecaBDE are available that still meet fire protection standards. These findings are broadly summarized in this section, with in-depth evaluations presented as Appendices.

### 3.1 Update of significant issues

In our 2006 report, we concluded that the level of uncertainty regarding three of the five questions about DecaBDE posed to the Agency in Public Act 94-100 was too large to allow us to adequately respond to these questions. Thus, we were not able to fully answer whether DecaBDE breaks down into more harmful chemicals, what health effects could result from exposure to DecaBDE, and whether DecaBDE alternatives were available that still met fire protection standards. Since issuing the 2006 report we have reviewed additional information regarding these issues. Our findings are summarized in this section and presented in detail in Appendix II.

We have reviewed several additional studies regarding the breakdown of DecaBDE by light. One study evaluating the fate of DecaBDE in soil and sediment suggests that limited degradation to lower-brominated PBDEs by light might occur, and also suggests that another potentially important breakdown pathway could occur on airborne soil particles. Another study adds to the evidence that DecaBDE can be broken down by light in water, although at apparently slow rates. We have reviewed additional studies about the breakdown of DecaBDE by microorganisms, which continue to build the case that microbes are able to debrominate DecaBDE under certain circumstances, also at apparently slow rates. Since most of these studies used a "primer" to activate the microbes, the environmental relevance of the results is difficult to determine. Finally, we reviewed several more studies concerning the breakdown of DecaBDE by animals that greatly expand our findings from the 2006 report. We now are confident that fish, mammals, and birds are capable of metabolizing DecaBDE into a variety of breakdown products, including lesser-brominated PBDEs and hydroxyl structures that could potentially resemble estrogen or the thyroid hormones. Unfortunately, there are still notable uncertainties about which of the breakdown products might be the most abundant and the most important toxicologically, so we are still not able to fully respond to this question.

Regarding the health effects of the PBDEs, we had identified liver, thyroid, reproductive/developmental, and neurological effects as the most important PBDE effects in the 2006 report, and noted that there were significant gaps in the data for all but liver effects. Studies we have reviewed of DecaBDE and other PBDEs since the 2006 report have filled some of these gaps. Studies with certain PBDEs, including some that are known breakdown products of DecaBDE, raise concern that the PBDEs may be able to

interfere with the normal hormonal control of reproduction and development. Five studies of PBDE effects on the thyroid/thyroid hormones strongly suggest that PBDEs and/or hydroxyl PBDE breakdown products, again including some that are known breakdown products of DecaBDE, are potentially able to cause thyroid effects in animals and humans. The neurological effects studies finding abnormal adult activity levels in mice exposed to DecaBDE as newborns that raised our concerns in the 2006 report have been followed up by two more studies from these researchers. They have repeated the original mouse study in a second species, the rat, and found similar results. They have also evaluated three known DecaBDE breakdown products in the same testing protocol used for DecaBDE, and found results similar to those obtained with DecaBDE. We further note that USEPA has chosen to use the original study with DecaBDE as the basis for proposing to update its Reference Dose for DecaBDE.

Unfortunately, this accumulating evidence of PBDE effects still contains considerable uncertainty about the role played by DecaBDE, and results from important follow-up reproductive/developmental and neurological effects studies with DecaBDE being conducted by the European Union are not yet available. Nevertheless, the level of uncertainty has decreased from our 2006 report, and further justifies an in-depth evaluation of potential alternatives to DecaBDE's uses.

### **3.2 Toxicity of DecaBDE alternatives**

As mentioned in Section 2.3 of this report and discussed more thoroughly in Section 6 of the 2006 report, there are a number of flame-retarding strategies available for products that do not require chemical flame retardants, and for which toxicity is not a concern. Examples include re-designing products to be less fire-prone, and using inherently flame-resistant fibers and light-weight metals. In order to evaluate whether potential chemical alternatives may be less toxic than DecaBDE, we found it necessary to develop a scoring approach that ranked DecaBDE and the alternatives on several key health and environmental effects. We decided that for human health scoring an evaluation of cancer, reproductive/developmental effects, systemic toxicity, and local (point-of-contact) effects was necessary. For environmental effects scoring, an evaluation was needed of acute and chronic aquatic toxicity, acute terrestrial toxicity, and whether an alternative could be a Persistent, Bioaccumulative, and Toxic (PBT) chemical. We then selected criteria to decide whether the level of concern for each of the health and environmental effects was high, moderate, low, or no concern.

We decided to use the results of this scoring approach to place the chemical alternatives into "bins" of overall concern: Potentially Unproblematic, Potentially Problematic, Insufficient Data, and Not Recommended. There is insufficient toxicity data available for the alternatives to say with certainty that they pose little or no risk and are therefore "safe" to use as flame retardants. However, some of the chemical alternatives do appear to be safer than DecaBDE.

Using this scoring approach, we evaluated DecaBDE and 16 alternatives that are either already major replacements for certain of DecaBDE's uses or are likely to become major

replacements as manufacturers move towards phasing out DecaBDE. This evaluation placed DecaBDE in the Potentially Problematic bin, and resulted in placing the selected alternatives into the four bins as follows.

Potentially Unproblematic:

- Bisphenol A diphenyl phosphate
- Resorcinol bis(diphenyl phosphate)
- Aluminum trihydroxide
- Magnesium hydroxide

Potentially Problematic:

- Triphenyl phosphate
- Tricresyl phosphate
- Diphenyl cresyl phosphate
- Tetrakis(hydroxymethyl) phosphonium chloride
- Antimony trioxide
- Boron compounds (borates other than zinc borate)

Insufficient Data:

- Diethylphosphinic acid, aluminum salt
- Melamine
- Red phosphorus
- Ammonium polyphosphates

Not Recommended:

- Polytetrafluoroethylene
- Zinc borate

A full discussion of the scoring approach and results of the scoring appears in Appendix III.

### **3.3 Affordability and availability of DecaBDE alternatives**

In order to gauge the relative affordability and availability of DecaBDE alternatives, the Agency undertook a widespread review of information relevant to these issues. We visited numerous industry and manufacturer websites, reviewed Material Safety Data Sheets, contacted various companies doing business in Illinois and trade associations representing industries that use DecaBDE now or have used it in the past, and reviewed numerous articles in the literature and on websites. Following this review of information and our discussions with the various contacts, we evaluated general and specific affordability and availability issues pertaining to five broad industry groupings, consumer electronics, other electrical applications and electronic products, medical devices, textiles and foams, and transportation. Based on our evaluations, it appears that there are only a few DecaBDE uses that still have affordability and/or availability concerns, while there are many uses/products for which a phase-out of DecaBDE is substantially complete or is



in progress. Our findings, summarized here and discussed in depth in Appendix IV, include:

- Consumer electronics – No significant affordability issues, with phase-out of DecaBDE substantially complete; manufacturers beginning phase-outs may need some time to complete fire protection tests and product re-design studies.
- Other electrical applications and electronic products (particularly wiring, cable, and electronic assemblies) – No significant affordability issues, with phase-out of DecaBDE substantially complete. Some additional, minimal product performance testing may still be required to complete the transition.
- Medical devices – Moderate affordability issues, extensive product testing still to be accomplished before phase-out possible.
- Textiles and foams – Remaining affordability issues related to uses in transportation industries discussed below; many options available to replace DecaBDE uses other than in transportation.
- Transportation – Significant affordability issues, related to performance and fire protection standards required by regulations and manufacturer’s specifications; significant time still needed to complete product performance and fire safety testing of plastics, electrical wiring, electronics, fuel systems, and upholstery.

In light of the substantial transition away from DecaBDE that is already occurring, it appears that many alternatives to DecaBDE’s uses have been found to be available and affordable by manufacturers. Whether these transitions have resulted from regulations and proposed regulations, market pressures, liability concerns, or other forces, it appears to us now that many users of DecaBDE are in the process of phasing it out or intend to phase it out as soon as reasonably possible.

## 4.0 RECOMMENDATIONS

In this report we have determined that DecaBDE is broken down in the environment and in organisms, although uncertainty remains about what are the most important breakdown products; that the evidence that DecaBDE and/or some of its breakdown products can be harmful to humans and animals is increasing; that there are a large number of alternatives to DecaBDE's many uses, and some of them are potentially unproblematic with regard to health and environmental effects and appear to be safer than DecaBDE; and that alternatives to DecaBDE's uses are in large part available and affordable while still meeting fire safety standards.

Based on these findings, the Agency concluded that some type of action is warranted to increase the use of alternatives to DecaBDE in Illinois rather than doing nothing new. Specifically, we recommend that the Governor support a managed state-level phase-out of several DecaBDE's uses. This approach should include the following elements:

- Establish a realistic target, such as year-end 2010, for the phase-out DecaBDE uses and industrial applications where there are available, affordable and potentially less toxic alternatives. Focus initially on DecaBDE used in electronics and textiles (excluding textiles used in the transportation sectors where availability and affordability is more limited). Given the widespread availability of affordable alternatives for these uses, a 2010 completion schedule should allow sufficient time for companies to make the transition away from DecaBDE, where it hasn't already happened. 2010 should also allow for sufficient product testing and toxicity research to help ensure that only safe alternatives are being selected. Legislation has been proposed in Connecticut and Washington that sets January 2010 as the completion date.
- Provide exemptions/extensions for those uses where alternatives are demonstrated not to be feasible. This will help encourage a managed transition that includes sufficient toxicity information to minimize health, environmental, and financial risks. The mechanism should require proper research and documentation to justify any exceptions/extensions.
- The managed phase-out could be accomplished through voluntary actions, negotiations, rules, and/or legislation.

In addition, the State should:

- Continue discussions with stakeholders to evaluate additional information pertaining to fire safety/flame retardants.
- Explore the creation of a clearinghouse among state environmental agencies as a central repository for information regarding flame retardants that can be made available to interested parties. For example, Illinois and 12 other states currently participate in the Interstate Mercury Education & Reduction Clearinghouse (IMERC). The IMERC provides a centralized approach to managing activities related to the reduction of mercury in products and waste.
- Modify state purchasing decisions to favor purchase of DecaBDE-free products. For example, when buying computer equipment, Massachusetts has a preference for equipment that does not contain certain hazardous constituents, including some flame-retarding materials.

## **ATTACHMENT A**

### **A Report to the General Assembly and the Governor in Response to Public Act 94-100**

#### **“DecaBDE Study: A Review of Available Scientific Research”**

#### **EXECUTIVE SUMMARY**

This report has been prepared to address the five issues posed by the Illinois Legislature to the Illinois Environmental Protection Agency in HB2572 regarding the use of Decabromodiphenyl ether (DecaBDE). The Agency reviewed numerous data sources, including some very recent information, pertaining to the five issues in order to respond in as thorough a manner as possible. However, data gaps exist in certain key areas that have hampered our ability to fully address some issues. In response to the five issues, we find that:

- DecaBDE is bioaccumulating in the environment, and levels are increasing in some types of samples (sediments, some top predators, and possibly human blood and breast milk).
- Humans are exposed to DecaBDE from many sources including the diet, workplace and home, with diet the primary source for adults and breast milk and house dust important sources for infants and small children.
- The most sensitive health effects from exposure to DecaBDE and/or lower-brominated congeners appear to be liver, thyroid, reproductive/developmental, and neurological effects, although the relevance of some of the effects reported in animal studies for human health risks has been questioned, and significant data gaps in the DecaBDE toxicity database have been identified; estimates of current human exposures to the PBDEs indicate that effects on the liver should not be occurring, but there is some potential that exposures could be occurring that are in the range of doses causing reproductive/developmental and neurological effects in two recent studies.
- DecaBDE can be broken down by ultraviolet light and direct sunlight, and also by metabolic processes in animals and microorganisms, but uncertainty and controversy exists about the extent of breakdown by light under environmentally relevant conditions and the human health implications of the breakdown products; thus, at this time we believe the information available does not allow us to confidently respond to the issue of whether DecaBDE breakdown products can harm human health.
- Effective alternatives exist for most of the plastics and textiles/fabrics uses of DecaBDE, although they are more costly, and these alternatives will likely reduce risks while maintaining an adequate level of flame retardant performance; however, significant toxicity data gaps exist for many of the main potential alternatives and further research is needed to better evaluate the health and environmental consequences of these alternatives.

We also reviewed the actions of other jurisdictions regarding the polybrominated diphenyl ethers (PBDEs). USEPA’s Voluntary Children’s Chemical Evaluation Program has determined that a

significant data gap exists regarding the environmental transport and fate of DecaBDE, and DecaBDE manufacturers will soon begin studies to fill these gaps. The European Union (EU) has included the PBDEs on a list of chemicals to be phased out of use in electrical and electronic equipment, but DecaBDE manufacturers have successfully petitioned for an exemption for DecaBDE from this ban. The EU will also conduct studies of the reproductive/developmental and neurological effects of DecaBDE to fill important gaps in the toxicity database. Several states have recently legislated bans on the use of the Penta- and OctaBDE flame retardant formulations in products, and Maine will ban DecaBDE in 2008 if effective alternatives to DecaBDE are identified. Some states have also required studies of DecaBDE to help decide what actions, if any, are appropriate for DecaBDE.

The research noted above on the potential for reproductive/developmental and neurological effects of DecaBDE and the studies on the environmental transport and fate of DecaBDE, plus other on-going or planned studies, should provide valuable information to assist in evaluating the issues raised in HB2572.

## **ATTACHMENT B**

### **Letter from Governor Blagojevich**

**OFFICE OF THE GOVERNOR  
SPRINGFIELD 62706**

**ROD R. BLAGOJEVICH  
GOVERNOR**

**MARCH 3, 2006**

Doug Scott, Director  
Illinois Environmental Protection Agency  
1021 N. Grand Avenue  
Springfield, IL 62702

Dear Director Scott,

Thank you for submitting your agency's report, "DecaBDE Study: A Review of Available Scientific Research," in response to the Brominated Fire Retardant Prevention Act (P.A. 94 100). Last year, I was pleased to sign this Act that banned two types of brominated flame retardants known to threaten human health and the environment.

As the Act required, Illinois EPA assessed the environmental and health effects of a third type of brominated flame retardant, DecaBDE, that is still used in many common household and consumer products, including textiles and electronics such as televisions and computers.

The report, which determined that people are exposed to DecaBDE through their diet, their homes and workplaces, concluded that uncertainty about the health effects of DecaBDE exposure is cause for concern. I am encouraged, however, by the finding that safer, effective alternatives to DecaBDE may exist that can still meet fire protection standards.

The report found that significant data gaps exist regarding the safety of DecaBDE and the availability of less toxic alternatives, therefore it is important for the protection of public health that we continue our efforts to determine the true risks of DecaBDE and to identify safer substitutes.

In keeping with the General Assembly's support for state adoption of a "precautionary approach" regarding brominated fire retardants, I am instructing Illinois EPA to conduct a follow-up study to answer critical questions that remain about the environmental and health effects of DecaBDE. We must determine whether safer alternatives are available so that manufacturers can reduce their reliance on toxic flame retardant chemicals while still ensuring their products meet fire safety standards.

If the study finds that alternatives to DecaBDE that meet fire protection standards are available, affordable and less toxic, then Illinois EPA should take the necessary steps to develop rules requiring use of these alternatives. Please submit this follow-up study to me and the Illinois General Assembly by January 31, 2007.

# APPENDIX I

## OVERVIEW AND DISCUSSION OF FIRE SAFETY ISSUES

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### Fire Safety As It Relates To DecaBDE Alternatives

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#### Affordability of DecaBDE Alternatives Is Closely Linked To Fire Safety

Affordability issues relating to DecaBDE alternatives are discussed in Appendix IV of this report. However, a key component of affordability includes the use of alternatives that promote adequate fire safety. From our review of fire safety issues as they relate to flame retardants (FRs) we conclude:

➔ **The only affordable DecaBDE alternatives are the ones that result in products that meet all required fire safety standards, and all DecaBDE alternative FRs currently offered by the chemical industry appear to result in compliance with applicable fire safety standards.**

In our extensive review of chemical company and consumer product manufacturer websites,

The president (2003) of the National Association of State Fire Marshalls stressed that trends related to flame retardants and fire safety are committed to “simultaneous achievement of highest possible standards for fire safety, health & environment and that all three areas are of equal importance.”<sup>1</sup>

associated articles on flame retardants, and discussions with corporations doing business in Illinois, **we did not see any evidence** that flame retardants being used as alternatives to DecaBDE do not meet all required fire safety standards. **All segments of industry only allow for the use of DecaBDE alternatives that meet fire safety**

**industry standards.**

The high costs associated with loss of life and property from fires that can result, if substandard flame retardant approaches are used, would be cost prohibitive for all segments of industry using FRs. The financial exposure from using flame retardants that do not result in consumer products that achieve fire safety standards would result in excessive financial exposure due to potential litigation surrounding excessive loss of life and property issues.

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### Overview of Fire Statistics/Fire Safety

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Fires are a major cause of death and injuries. It is estimated that an average of 4,300 persons are killed in the United States each year and 27,000 are injured.<sup>2</sup> The role of flame retardants is to make materials harder to ignite, and if once ignited, in many cases to reduce the rate of heat release or the rate at which flames spread to limit the total quantity of material involved in a fire. The American Fire Safety Council (AFSC) had the following fire safety statistics on their website:<sup>3</sup>

- In 2005 fires in the U.S. claimed nearly 3,600 lives, injured close to 18,000 and resulted in property losses of about \$10 billion.

- More than 50% of fire deaths in the U.S. are due to ignition of upholstered furniture and mattresses.
- The number of residential fires per year in the U.S. is 396,000 or 78% of all fires with home fire deaths accounting for 82% of all civilian deaths.

According to the Supresta website (a leading manufacturer of flame retardants), a home structure fire is reported every 79 seconds, and someone dies from a home fire every 135 minutes in America.<sup>4</sup> According to an AFSC news release, on February 16, 2006 the U.S. Consumer Product Safety Commission (CPSC) unanimously approved a new federal standard for mattress flammability. By limiting the spread and intensity of a mattress fire and increasing escape time, CPSC estimates that the mandatory standard could save hundreds of lives and prevent more than 1,000 injuries every year. The CPSC is also developing an upholstered furniture standard.<sup>6</sup>

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## Overview of Flame Retardants and Fire Safety Standards

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### Flame Retardants

The SpecialChem (SpecialChem is a knowledge and solution provider in the domain of specialty chemicals including flame retardants) website discusses the following: flame retardants are recognized as providing lifesaving benefits to consumers by lowering product ignitability, fire

**Regulations drive FR revenues in the United States in most of the applications. As government bodies demand the use of less-toxic materials, the non-halogenated FR market is expected to grow. The ban on brominated compounds is expected to increase the demand for non-brominated ones, which is a positive sign for manufacturers that produce the latter.<sup>5</sup>**

development rates and smoke production. Flame retardants are additives that can be added to or applied as a treatment to organic materials such as plastics and textiles. Alternatively, they can be used during the production process as a chemical modification of some plastic materials. Their main effect is to reduce the chances of a fire starting by providing increased resistance to

ignition. Even if ignition does occur, flame retardants will act to delay the spread of flame, providing extra time in the early stages when the fire can be extinguished or an escape can be made.<sup>7</sup>

### Fire Safety Standards in the Flame Retardant Industry

The Lowell Center report titled: “**Decabromodiphenylether: An investigation of Non-Halogen Substitutes in Electronic Enclosure and Textile Applications**” states that roughly 80% of DecaBDE use in the U.S. is believed to be in electronic enclosures for televisions, computers, medical equipment etc. Much of the remaining 20 percent is used in textile applications. The chief fire safety standards for electronic enclosures are the UL 94 component standards. The UL 94 component standards range from UL94 HB (the lowest standard), which involves a horizontal burn, to successively more stringent vertical burning test (Class UL 94 V-2, V-1, V-0 and 5V). Some manufacturers of televisions and computers have successfully transitioned away from DecaBDE through the re-design of their products including the use of alternative resins that use phosphorous based FRs.<sup>8</sup>

For textiles there are numerous federal, state, and voluntary fire safety performance standards that drive the use of flame retardants in textiles. The most significant of these include those promulgated by the State of California Bureau of Home Furnishings and Thermal Insulation and the Consumer Product Safety Commission.<sup>9</sup>

Flame retardant manufacturer websites extensively promote the fire safety of all of their FR products. FR manufacturer Chemtura's website (Chemtura was formed in 2005 from the merger of Crompton Corporation and Great Lakes Chemical Corporation) provides the following overview of the make-up of fire safety standards:

- Laws and regulations define the necessary minimum levels of fire safety,
- Technical standards for products define which fire test has to be applied and what the criteria are,
- Fire test standards define the method of testing for reaction to fire and the measured parameters (e.g., time to ignition, heat release...),
- Flame retardants can be added to some materials in order to achieve the necessary safety level (i.e., pass the relevant fire test) thus enabling their use to conform to regulations and to offer the required level of fire safety to the public.<sup>10</sup>

Chemtura's website goes on to state that: conformity to fire safety regulations is tested by product manufacturers, officially recognized testing institutes and independent experts according to methods outlined in the standard for each particular fire test. Fire tests are designed to provide data on combustibility, ignitability, flame spread, heat release, and smoke and gas generation for both flame retarded and non-flame retarded products and components. Without fail, these tests

demonstrate that the use of flame retardants inhibits ignition and reduces combustibility – particularly in the early stages of a fire, thus lengthening the potential escape time and providing additional time for fire suppression actions to be taken.<sup>11</sup>

**New environmentally safe FR additives have been developed to cater to the increasing demand for non-halogenated FRs. These non-halogenated FR additives are designed to act as an effective replacement for the HFRs, which are being gradually phased out.<sup>12</sup>**

In our review of chemical industry and manufacturer's websites (Chemtura and Supresta) we consistently saw extensive discussions of flame retardants (both halogenated/brominated and non-halogenated/non-brominated alternatives to DecaBDE) and the associated **fire safety standards** that are met through

the use of the chemical company's FR products. Examples of standards contained and discussed on chemical industry websites include:

- Regulation- California Technical Bulletin 117 (TB117), United States, Sets flammability standards for furniture,
- Regulation- California Technical Bulletin 603 (TB63) "Mattress Standard", in California all residential mattresses, box springs and futons must be open-flame resistant,
- Regulation-Underwriters' Laboratories 94, (UL94) Global, Electrical and Electronic equipment, and
- Motor Vehicles Standard 302, Global, Motor vehicles (polyurethane foam).



A detailed review of **chemical industry** and product **manufacturer websites** also shows that flame retardants are discussed in a manner that addresses environmental, health, and fire safety issues. For example websites for Supresta and Chemtura (major manufacturers of flame retardants) state:

“**Supresta** recognizes its responsibility to encourage sustainable and environmentally preferable approaches to fire safety. Supresta entered into a partnership with the United States EPA, furniture manufacturers, and non-governmental groups in the EPA’s Design for the Environment Program. This innovative program allowed Supresta to develop environmentally sound approaches to fire safety as certain flame retardants were being phased out.”<sup>13</sup>

“In today’s marketplace OEMs are faced with designing products to meet increasingly stringent fire safety standards, while regulatory and environmental policies restrict flame retardant choices. Often, challenges are presented by the regulation of other materials affecting the performance of the flame retardant in the final product. Great Lakes Chemical, [merged with Crompton Corporation to form **Chemtura**] the world’s largest flame retardant supplier, is well placed to meet the increasing demands of the flame retardant marketplace in order to develop sustainable fire retardant solutions to meet emerging needs.”<sup>14</sup>

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### **Flame Retardant Chemical Industry: Websites Promote Fire Safety Including DecaBDE Alternatives**

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**Non-halogenated alternatives are more expensive than HFRs and their performance is often inferior. However, manufacturers of flame retardants are working feverishly to develop novel technologies which can match the performance of halogenated compounds...Non-traditional flame retardant technologies using combinatorial effects, nanocomposites and synergistic formulations are most promising as future long-term solutions to the phasing out of halogenated compounds.**<sup>15</sup>

Chemical industry websites fully discuss fire safety standards and chemical companies manufacturing FRs highlight and stress the safety of their products with regard to fire safety. A review of chemical industry websites confirms that all flame retardants being offered, including those that can be used as alternatives to DecaBDE, currently meet all required fire safety standards/regulations.

We saw numerous discussions on chemical industry websites regarding the wide variety of brominated and non-brominated FRs that provide fire safety to levels that meet all fire safety requirements. Consequently, we concluded that the DecaBDE alternatives do not result in any affordability issues as they relate to fire safety and the minimization of losses due to damage to property or injury/loss of life.

The chemical industry websites clearly show that the industry is offering fire safe alternatives to halogenated/brominated FRs like DecaBDE. For example, **Chemtura’s website** highlights the following **market and regulatory trends** resulting in their development of fire safe, halogen free FRs; some of which could be used as fire safe alternatives to DecaBDE.<sup>16</sup>

- Halogen free alternatives in electrical components,
- Non-halogen sentiment at OEMs regarding electrical components,
- Halogen-free alternatives for plastic conduit for wire and cable applications,
- Japan and Europe are more active in halogen-free solutions for automotive cables,
- Consumer products industry includes an EU/OEM drive to non-halogen technologies,
- Consumer electronics OEMs pushing halogen-free circuit board materials and balancing cost performance,
- OEMs pushing for lead-free, non-halogen polymeric materials and balancing the cost performance,
- Government institutions adopt “green” purchase policy, leading more OEMs to convert from halogenated to non-halogen materials.

Chemtura is a leading global producer of non-halogenated phosphorus based flame retardants (e.g., Reofos® NHP, Reogard® 1000 product) many of which could be used in place of brominated/halogenated FRs like DecaBDE depending on the specific product application.

**Regulations and brand image concerns of Original Equipment Manufacturers (OEMs) customers act as key drivers for the non-halogenated FR market in the United States. However, the key issue in the FR industry is to replace existing halogenated FRs with non-halogenated FRs that have similar efficacy. The usage of less toxic additive systems is one way for FR manufacturers to address this issue.<sup>17</sup>**

A review of fire safety literature at all levels of the FR industry frequently discusses an **integrated approach** that takes into account **fire safety, health, and the environment**.

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- <sup>11</sup>Ibid, [www.chemtura.com](http://www.chemtura.com).
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## **APPENDIX II**

### **UPDATE OF SIGNIFICANT ISSUES FROM 2006 REPORT**

In the Agency's 2006 report to the General Assembly and the Governor in response to Public Act 94-100, we stated that we could not confidently respond to three of the five questions posed by Public Act 94-100 because of significant data gaps. Specifically, we were not fully able to answer whether DecaBDE breaks down into more harmful chemicals, what health effects could result from exposure to DecaBDE and whether current levels of exposure could produce these effects, and whether potential DecaBDE alternatives could reduce health risks while still maintaining an adequate level of flame retardant performance. This appendix presents an update of the data available to us since the 2006 report pertaining to these issues, and whether changes in our responses to the three questions might be warranted by the additional data.

#### **Breakdown of DecaBDE**

In the 2006 report the Agency found that DecaBDE can be broken down by light and by metabolic processes in animals and microorganisms. We noted that there was consensus that light can break DecaBDE down into nona-, octa-, and some heptaBDEs, but that there was disagreement whether the more toxic lower-brominated PBDEs can be produced by light under environmentally relevant conditions (i.e., other than in the presence of organic solvents). We also noted that a variety of penta- through nonaBDE congeners have been identified as DecaBDE breakdown products in fish and rats, and nona- and octaBDEs have been found as microbial breakdown products under anaerobic conditions. In addition, we found that hydroxyl breakdown products have been found in rats dosed with DecaBDE, raising the possibility of an additional class of toxic breakdown products. However, as with breakdown by light, there was disagreement concerning the extent to which the lower-brominated congeners that have been detected in animals and fish (wild and domestic) derives from breakdown of DecaBDE versus from use of the Penta- and OctaBDE commercial formulations. It was also not clear at that time what potential harm might derive from the hydroxyl breakdown products.

Since the 2006 report, a number of additional studies of the fate of DecaBDE in the environment and in organisms have been reviewed by the Agency. These studies further evaluated breakdown by light and other abiotic processes, metabolism by microorganisms, and metabolism by animals.

Breakdown by light and other abiotic processes - Ahn et al. (2006a) studied the debromination of DecaBDE adsorbed onto two types of clay, three metal oxides, and organic-rich sediments by both ultraviolet (UV) and natural light. They found that debromination occurred in both types of light on the clays but not on the metal oxides; that the half-life (the time required for disappearance of half the original amount of a chemical) of DecaBDE on clay is an order of magnitude longer under natural versus UV

light; that debromination under UV light in organic-rich sediment is 3-4 times slower than in clay; and that a number of tri- to nonaBDEs are produced by both types of light in clay. The results of this study suggest that DecaBDE may be debrominated in soils and sediments from natural sunlight, although the limited extent of light penetration makes this a relatively minor pathway for breakdown. This is reinforced by the results of a study evaluating the fate of PBDEs applied to soil in sewage sludge (Sellstrom et al., 2005), in which no evidence of light-mediated debromination of DecaBDE in soil was seen. Of potentially greater relevance, however, is the possibility that breakdown on airborne clay particles by sunlight could be an important fate process for DecaBDE.

In a second study from these researchers, Ahn et al. (2006b) investigated the breakdown of DecaBDE by one of the metal oxides, manganese oxide (MnO<sub>2</sub>), found in the first (2006a) study not to cause breakdown of DecaBDE in light. In the second study, DecaBDE was exposed to MnO<sub>2</sub> in water to which an organic solvent, tetrahydrofuran, was added, and a number of tetra- to nonaBDE congeners were found. When this study was repeated with the naturally-occurring organic chemical catechol (found in soil humic material and tannins) added to water instead of tetrahydrofuran, breakdown of DecaBDE was seen only at a very high catechol concentration and the amount of breakdown was small. In a similar study, Keum and Li (2005) exposed six PBDE congeners dissolved in another organic solvent, ethyl acetate, to powdered iron or the mineral iron sulfide. The results for DecaBDE found significant breakdown to numerous tri- to nonaBDEs with powdered iron, whereas exposure to the more environmentally relevant iron sulfide produced a similar array of lower-brominated congeners but at a greatly reduced rate.

The results from the studies using organic solvents are consistent with findings noted in the Agency's 2006 report that DecaBDE can be debrominated in the presence of organic solvents, but questions about the environmental relevance of such findings still remain. However, the results from the study using catechol add to the evidence that DecaBDE can be broken down in water, although at apparently slow rates.

Metabolism by microorganisms – In the 2006 report, the Agency noted that one study (Gerecke et al., 2005) found that DecaBDE could be broken down to octa- and nonaBDE by microbes in sewage sludge, which suggested that DecaBDE could be broken down in other anaerobic compartments of the environment such as some soils and sediments. The environmental relevance of this study has been questioned however, since the experimental procedure used three organic chemical primers that would not likely be present in the environment to “jump start” the microbial activity, and the half-life of about 700 days found for DecaBDE in sludge in the study questions the applicability of these results to typical sewage plants in light of the much shorter residence time of their digesters. Thus, Gerecke et al. (2006) followed up this study using the same experimental procedures but with no or one primer and found that breakdown still occurred, but at a slower rate. This study also reports on preliminary results from an evaluation of the breakdown of DecaBDE in a full-scale anaerobic sewage digester with a residence time of 28 days, and finds equivocal evidence that breakdown does occur under these conditions.

Two studies provide evidence that microbial breakdown of DecaBDE occurs in anaerobic sediments. In a progress report to USEPA for an on-going study, Nies et al. (2005) found that after 3.5 years of exposure in anaerobic sediment cultures, DecaBDE was broken down to hexa- to nonaBDEs, with a calculated half-life of over ten years. Interestingly, in a parallel experiment with an organic solvent added to the cultures the half-life was 18 seconds, providing a vivid illustration of the enhanced breakdown of DecaBDE in the presence of organic solvents. In the second study, Skoczynska et al. (2005) evaluated the breakdown of DecaBDE in anaerobic sediment cultures to which organic solvents were added, and found rapid breakdown to nonaBDEs. These studies provide evidence that DecaBDE may be broken down to lower-brominated congeners in sediments.

In another study of the potential for microbial breakdown of DecaBDE, He et al. (2006) evaluated the debrominating capabilities of certain anaerobic bacteria known to be able to metabolize highly chlorinated organic chemicals. They found that *Sulfurospillum multivorans* was able to debrominate DecaBDE to hepta- and octaBDEs, whereas *Dehalococcoides* species were not able to debrominate DecaBDE. Conversely, *Dehalococcoides* species were able to produce a variety of di- to heptaBDEs from a commercial OctaBDE formulation, whereas *S. multivorans* was unable to debrominate the OctaBDE formulation. The environmental relevance of this study is questionable, however, since the microbial cultures were primed with Trichloroethylene, which is not usually present in the environment other than at contaminated industrial sites.

Metabolism by animals – We have reviewed several studies of the breakdown of PBDEs by animals since issuing the 2006 report, which greatly expand our findings from that report. In the 2006 report, we noted that rainbow trout and carp were able to debrominate DecaBDE down to hexaBDEs and pentaBDEs, respectively, and that certain hydroxyl structures have been identified as breakdown products of DecaBDE in rats that might result in structures similar to estrogen and the thyroid hormones. Taken together, the studies reviewed since the 2006 report demonstrate that animals are capable of metabolizing PBDEs to a variety of breakdown products.

In a follow-up to the study cited in the 2006 report, Stapleton et al. (2006) evaluated whether DecaBDE breakdown products could accumulate in trout, and found that several hepta- to nonaBDEs accumulated over a five-month period. This study also evaluated the extent of metabolism of DecaBDE by enzymes isolated from trout and carp livers, and found that carp enzymes produced a greater amount of debromination and a wider variety of breakdown products than trout enzymes. In other studies with fish, Lebeuf et al. (2006) found enrichment of octa- and nonaBDEs, but not lower-brominated congeners, in Atlantic tomcod exposed to the commercial DecaBDE formulation (although it was not clear to what extent this was due to breakdown versus impurities in the DecaBDE product), and Tomy et al. (2004) found three BDE congeners in lake trout that were not present in the diet or the control fish that they noted as evidence of debromination.

Studies also demonstrate that mammals and birds are capable of metabolizing DecaBDE. Huwe (2005) found that one octaBDE and possibly other octa- and nonaBDEs accumulated in rat liver after exposure to DecaBDE in the diet. In a study in which cows

were exposed to feed environmentally contaminated primarily with DecaBDE and also with much lower levels of nonaBDEs, Kierkegaard et al. (2007) stated that the most likely explanation for the differences in congener profiles between feed and tissue residues is debromination of DecaBDE (down to heptaBDEs). Malmberg et al. (2005) identified 16 hydroxyl and 2 dihydroxyl metabolites in the blood of rats given a mixture of 7 BDE congeners (including DecaBDE), which adds to the concern expressed in our 2006 report about the potential for hydroxyl metabolites being formed that are similar in structure to estrogen and the thyroid hormones. In humans, Thuresson et al. (2006) evaluated the half-lives of hepta- to DecaBDEs in workers occupationally exposed to PBDEs, and found that DecaBDE's half-life of about 15 days was shorter than the half-lives of the other PBDEs evaluated (18-91 days). They concluded that DecaBDE is more easily metabolized and/or more easily excreted to account for these differences. Finally, Van den Steen et al. (2007) showed for the first time debromination of DecaBDE in birds, finding mainly octa- and nonaBDEs present in the muscle and liver of starlings exposed to DecaBDE.

In summary, the studies on the fate of DecaBDE in the environment and in organisms we have reviewed since the 2006 report continue to suggest that DecaBDE can be broken down by abiotic and biotic processes. These processes produce a number of less-brominated congeners or hydroxylated structures, some of which may be of concern for their health effects. It is still not clear what are the most important and/or most abundant of these breakdown products since there are still some notable uncertainties. As a result of these uncertainties, we will continue to evaluate the health and environmental effects of other PBDEs as well as DecaBDE in this report.

### **Health Effects of DecaBDE and Other PBDEs**

In the 2006 report, the Agency noted that there is surprisingly little human health effects data available considering the large volume of PBDEs used since their introduction, while there are numerous reports of the effects of the PBDEs on laboratory animals. We decided to focus our review on those organs and tissues for which effects are seen at lower doses, since these effects would be most relevant to human health risks. Thus, we identified liver, thyroid, reproductive/developmental, and neurological effects as the key PBDE effects at lower doses, and noted that there were significant gaps in the data for all but liver effects. We also noted that studies to further evaluate reproductive/developmental and neurological effects were to be carried out by the European Union.

Since issuing the 2006 report, we have not become aware of any additional significant human data, nor have we seen any results from the European Union studies. In the only study of potential effects of PBDEs in humans, Weiss et al. (2006) followed up a study that found an association between organohalogen chemical exposure and osteoporosis in seals from the Baltic Sea with a study evaluating associations of these chemicals in the blood of Swedish fishermen's wives with markers for osteoporosis. No associations were found between any of the chemicals and the women's bone density or any biochemical markers of bone metabolism.



We have reviewed several additional animal studies of PBDE effects since issuing the 2006 report. These studies address reproductive/developmental, thyroid, and neurological endpoints, adding to the databases for these health effects.

Reproductive/developmental effects – Tseng et al. (2006) studied the effects of DecaBDE on sperm functions in male mice exposed from post-natal days 21-70 (i.e., post-weaning to puberty). They found decreases in the electrical potential of sperm membranes and in one of five measures of sperm movement, and an increase in the generation of one of two reactive oxygen species associated with cell membrane damage. The Lowest Observable Adverse Effect Level (LOAEL) for these effects was 500 mg/kg/d. It is somewhat difficult to evaluate potential human health risks from this study since there were no effects found on many other measures of sperm function, sperm structure, and sperm DNA content, and the LOAEL is relatively high.

In another study of the potential reproductive/developmental effects of the PBDEs, Lilienthal et al. (2006) examined the effects of exposure to 2,2',4,4',5-pentabromodiphenyl ether (BDE-99) in rats. In this study, pregnant rats were exposed on days 10-18 of gestation to 1 or 10 mg/kg/d of BDE-99 and the offspring were evaluated for several reproductive/developmental endpoints. The authors found large decreases in circulating sex steroids and reduced anogenital distance (a measure of masculinization), and an increased sweet preference (a measure of feminization) in the male offspring. In the female offspring, the lower dose resulted in a decrease in primary ovarian follicles while the higher dose caused a decrease in secondary follicles.

Nakari and Pessala (2005) evaluated the ability of three BDEs (2,2',4,4'-tetrabromodiphenyl ether (BDE-47), BDE-99, and 2,3,3',4,4',5,5',6-octabromodiphenyl ether (BDE-205)) to produce the egg protein vitellogenin (normally only produced by female fish) in cultures of liver cells from male trout. All three PBDEs caused vitellogenin production, with BDE-205, a known breakdown product of DecaBDE, being most potent. In another *in vitro* study, Hamers et al. (2006) found that 6-hydroxy-BDE-47 (one of the 16 hydroxyl metabolites identified by Malmberg et al. (2005) above as breakdown products of BDEs) was the most potent anti-estrogenic chemical tested in their protocol. On the other hand, many lower-brominated PBDEs exhibited anti-androgenic activity, with the environmentally widespread 2,2',4,4',6-pentabromodiphenyl ether (BDE-100) being 13 times more potent than the anti-androgenic drug Flutamide used as the positive control in this part of the study. It should be noted that DecaBDE and 2,2',3,3',4,4',5,5',6-nonabromodiphenyl ether (BDE-206) were inactive in these tests.

The results from the Lilienthal et al., Nakari and Pessala, and Hamers et al. studies add to the concern that PBDEs may be able to interfere with the normal hormonal control of reproduction and development. Whether the levels of PBDEs in the environment are sufficient to interfere with hormonal control, and what part DecaBDE might play in such interference, require further study.

Thyroid effects – Two studies with frogs demonstrate the potential for PBDEs to cause thyroid-related effects. Balch et al. (2006) exposed tadpoles to BDE-47, BDE-99, and a commercial PentaBDE formulation and found that all three treatments delayed the normal metamorphosis into frogs, an event that is known to be highly dependent on thyroid hormones. In a similar study, Schriks et al. (2006) exposed tadpole tail tips in organ culture to BDE-206 in the presence or absence of the thyroid hormone triiodothyronine (T3), which is known to cause the regression of tail tips as the tadpole undergoes metamorphosis. They found that BDE-206, at concentrations as little as five times in excess of T3, was able to halt the regression of the tail tips, whereas BDE-206 in the absence of T3 had no effect. These results suggest that BDE-206 is a fairly potent inhibitor of T3 action.

A study with kestrels suggests that PBDEs can affect thyroid hormone levels in birds. Fernie et al. (2005) injected eggs with a mixture of BDE-47, BDE-99, BDE-100, and 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153) at environmentally relevant (i.e., at levels found in Great Lakes gull eggs) concentrations and found decreased levels of the thyroid hormone thyroxine (T4), but not T3. Another study of rats exposed to a PentaBDE formulation during lactation (Ellis-Hutchings et al., 2006) found decreased levels of T4 in both mothers and offspring, and the magnitude of the decrease was worsened in mothers that were marginally deficient in Vitamin A. Thyroid effects were also evaluated in the *in vitro* study cited above by Hamers et al., in which BDE-206 caused a significant decrease in T3 activity, and 6-OH-BDE-47 was a fairly potent competitor to T4 for binding to the thyroid hormone transport protein transthyretin. The results of these five studies continue to build concern for the potential of PBDEs to cause thyroid effects in humans and wildlife.

Neurological effects – A study by Alm et al. (2006) investigated the effects of a single dose of BDE-99 on newborn mouse brain at the protein level. They used various imaging techniques to evaluate changes in proteins in the brain, and found numerous changes indicative of degeneration. In an abstract of another study of neurological development (submitted for publication but still being peer-reviewed), Cressey et al. report deficits in two measures of neurological development in mice exposed to DecaBDE from days 2-15 after birth. They also report that male mice experienced hyperactivity in adulthood, and both sexes exhibited an abnormal response to nicotine challenge. These results suggest neurological effects similar to those discussed in our 2006 report.

In the 2006 report, we focused on a series of studies from a Swedish laboratory in which newborn mice were exposed to various PBDEs during a critical period of neurological development and then evaluated for activity levels at 2, 4, and 6 months of age. We noted that all the PBDEs tested in this protocol (BDEs 47, 99, 153, and DecaBDE) caused abnormal activity levels that worsened with age, suggesting that the neurological changes were permanent. We further noted that the study with DecaBDE (Viberg et al., 2003) has been criticized for certain procedural and statistical problems, calling into question its relevance for human risk evaluation.

This laboratory has since published two additional studies that expand the database regarding the neurotoxic potential of the PBDEs. Viberg et al. (2007) have repeated the original 2003 DecaBDE study with mice using a second rodent species, the rat, and has obtained similar results, finding disruption of normal adult activity levels following exposure during the post-natal period. This study also found that the adult rats responded abnormally to nicotine, potentially identifying nicotinic receptors in the brain as targets for the toxic effects of the PBDEs. In the second study, Viberg et al. (2006) evaluated exposure to 2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE-183), 2,2',3,4,4',5,5',6-octabromodiphenyl ether (BDE-203), and BDE-206 (all DecaBDE breakdown products) in mice in the same experimental protocol. The results of this study again show changes in activity levels, and mice exposed to BDEs 203 and 206 also were found to have deficits in a water maze test indicative of learning impairment.

The results of the unpublished study by Cressey et al. and the studies by Viberg et al. continue to build a case that the PBDEs can cause adverse neurological effects upon exposure to the fetus and newborn. We note with interest that the draft *Toxicological Review of Decabromodiphenyl Ether (BDE-209)*, issued by USEPA for public comment prior to updating this chemical's information in the Integrated Risk Information System (IRIS; USEPA 2006), has chosen the Viberg et al. (2003) study with DecaBDE as the basis for its proposed Reference Dose of 0.007 mg/kg/d, in spite of the noted procedural and statistical problems.

In summary, the accumulating evidence for reproductive/developmental, thyroid, and neurological effects of the PBDEs continues to be a cause for concern about these chemicals. There is still some uncertainty about the role of DecaBDE in these effects, but the level of this uncertainty has decreased since the 2006 report. Thus, an evaluation of potential alternatives to DecaBDE is warranted, in order to help manage any transition away from DecaBDE that might occur in the future.

### **Health Effects of DecaBDE Alternatives**

As stated above, the Agency noted in the 2006 report that significant gaps existed in the toxicological database for potential DecaBDE alternatives. In responding to the request from the Governor to evaluate DecaBDE alternatives, the Agency has reviewed numerous studies and reports regarding the health and environmental effects of potential alternatives. The results of this review are presented in Appendix III.

### **Summary**

Our review of additional studies and reports pertaining to the breakdown of DecaBDE, health effects of DecaBDE and other PBDEs, and health effects of DecaBDE alternatives has expanded our knowledge base in these areas. Regarding the breakdown of DecaBDE, it is obvious that light can debrominate DecaBDE in soil, water, sediment, and air, and that anaerobic degradation of DecaBDE by microorganisms in sewage and sediments can occur in some circumstances. It is also clear that animals are capable of metabolizing DecaBDE to a variety of breakdown products. However, it can be

questioned how much abiotic and microbial degradation occurs under normal environmental conditions, and it is not clear whether the more toxic lower-brominated PBDEs are produced in significant quantities by any of these pathways. Thus, we now have an expanded knowledge base of the fate of DecaBDE in the environment, but at this time we are still not able to fully respond to the question of whether DecaBDE breaks down into more harmful chemicals.

Regarding the health effects of DecaBDE and other PBDEs, evidence continues to accumulate that certain PBDEs are capable of interfering with the normal hormonal control of reproduction and development and with normal thyroid function. Evidence is also building that certain PBDEs can cause neurological deficits in the fetus and newborn. These effects continue to raise concerns about the PBDEs, although the role of DecaBDE in some of the effects is uncertain. We await the results of the reproductive/developmental and neurological effects studies of DecaBDE being conducted by the European Union to better answer the question of what health effects could result from exposure to DecaBDE.

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## **APPENDIX III**

### **TOXICITY EVALUATION OF ALTERNATIVES**

The letter from Governor Blagojevich requests the Agency to evaluate whether safer alternatives to DecaBDE are available. Since the letter did not specify the criteria for determining whether an alternative is less toxic than DecaBDE, we developed a scoring approach that is similar to approaches used in other evaluations of DecaBDE alternatives. This approach and its criteria and the results of the alternatives' toxicity evaluations are presented below. We have decided not to evaluate a large number of potential alternatives in order to focus on those already being used and those most likely to be used in large quantities in the near future. We have also made a policy decision not to evaluate bromine- and chlorine-containing alternatives out of concern for the likely generation of halogenated dioxins and furans if these chemicals are involved in fires or incinerated.

Two general issues should be raised before discussion of individual DecaBDE alternatives. First, after evaluating the toxicity databases for the alternatives we noted that the database for DecaBDE is the most complete of the various flame retardants. This makes it somewhat difficult to state with confidence that a potential alternative is "less toxic" than DecaBDE because of the uncertainty associated with gaps in the data. In planning discussions on how to respond to the Governor's request, we initially intended to develop a list of "Recommended" alternatives to DecaBDE, but after evaluating the data for the alternatives we decided this would not be appropriate due to the uncertainties. Instead, we settled on the approach described below.

The second issue relates to an issue we raised in the 2006 report, in which we expressed concern that a widespread switch to phosphorus-based alternatives could have potentially hazardous indirect consequences. This concern derives from lack of data regarding the amounts of highly toxic phosphine gas that might be generated during the various stages of a fire. If significant amounts of phosphine are generated, this could potentially increase the toxicity of fire gases and lead to an increase in fire-related deaths and injuries. In spite of continued searches, we have still not found any relevant information on this issue.

#### **Scoring Approach**

In planning sessions, we discussed which toxicity endpoints were most relevant to evaluation of DecaBDE alternatives, and we also reviewed the approaches used in other evaluations of PBDE alternatives (Washington 2006; National Research Council 2000; Fisk et al., 2003; Rossi and Heine, 2006). We decided that it was necessary to evaluate human health risks from cancer, reproductive/developmental effects, systemic toxicity, and local (point-of-contact) effects; environmental risks from acute and chronic aquatic effects and acute toxicity to terrestrial species (chronic toxicity being addressed by the human health endpoints other than cancer); and whether a chemical displayed the characteristics of a Persistent, Bioaccumulative, and Toxic (PBT) chemical, in order to



adequately compare the toxicities of DecaBDE and potential alternatives. We also selected criteria for these endpoints that evaluated whether the level of concern for the endpoint is High, Moderate, Low, or of No Concern, in order to help inform the overall level of concern for an alternative in relation to DecaBDE. The rating scheme for evaluating DecaBDE alternatives is presented in the attached table. The information from this scheme can be amended with other pertinent information, such as biodegradation potential, toxicity of known and likely breakdown products, environmental monitoring data, physical/chemical data suggesting high mobility, product end-of-life issues, etc., to help inform the judgment of the overall level of concern for a chemical.

We decided to use the results of this scoring approach to place the chemical alternatives into “bins” of overall concern: Potentially Unproblematic, Potentially Problematic, Insufficient Data, and Not Recommended. There is insufficient toxicity data available for the alternatives to say with certainty that they pose little or no risk and are therefore “safe” to use as flame retardants. However, some of the chemical alternatives do appear to be safer than DecaBDE.

## Results

Using the scoring approach described above, we evaluated DecaBDE and the following potential DecaBDE alternatives (CAS # in parentheses):

- Bisphenol A diphenyl phosphate (181028-79-5)
- Resorcinol bis(diphenyl phosphate) (57583-54-7)
- Triphenyl phosphate (115-86-6)
- Tricresyl phosphate (1330-78-5)
- Diphenyl cresyl phosphate (26444-49-5)
- Tetrakis(hydroxymethyl) phosphonium chloride (124-64-1)
- Diethylphosphinic acid, aluminum salt (225789-38-8)
- Polytetrafluoroethylene (9002-84-0)
- Melamine (108-78-1)
- Aluminum trihydroxide (21645-51-2)
- Magnesium hydroxide (1309-42-8)
- Antimony trioxide (1309-64-4)
- Red phosphorus (7723-14-0)
- Boron compounds (Zinc borate=1332-07-6; other borates represented by Boric acid=10043-35-3)
- Ammonium polyphosphates (14728-39-9; 68333-79-9)

As a result of the evaluation, the alternatives were placed into the various bins as described in the following subsections. We relied on other published evaluations of health and environmental effects of flame retardants (Stuer-Lauridsen et al., 2000 and 2007; Berglund 1995; Leisewitz et al., 2000; Washington 2006; HDP 2004), United Nations Environment Program (UNEP) documents, USEPA’s Integrated Risk Information System (IRIS), and other peer-reviewed studies in evaluating the potential

alternatives. Brief discussions of the chemicals' overall evaluations are presented here, with scoring summaries presented in the attachment at the end of this appendix.

Potentially Unproblematic – The alternatives meeting the criteria for Potentially Unproblematic include:

- Bisphenol A diphenyl phosphate: Low Concern for most endpoints based on existing data and professional judgment; key data deficiencies include cancer, two-generation reproductive/developmental effects, and chronic aquatic toxicity studies; some concern due to generation of Bisphenol A, a chemical identified by the Agency as a probable endocrine disruptor (IEPA, 1997), as a breakdown product, although no data on potential amounts were found.
- Resorcinol bis(diphenyl phosphate): No Concern for reproductive/developmental effects; no chronic aquatic toxicity data; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include cancer, chronic systemic effects, and chronic aquatic toxicity studies.
- Aluminum trihydroxide: No cancer data, but risk likely to be low based on professional judgment; Low Concern for other effects based on existing data and professional judgment (human exposure data from antidiarrheal and antacid uses); key data deficiencies include cancer, neurological effects, and chronic aquatic toxicity studies; acute aquatic toxicity likely only at very low pH.
- Magnesium hydroxide: No cancer or reproductive/developmental data, but risk likely to be low based on professional judgment; Low Concern for other effects based on existing data and professional judgment (human exposure data from food, medicinal, and cosmetic uses); key data deficiencies include cancer, reproductive/developmental, and chronic aquatic toxicity studies.

Potentially Problematic – In addition to DecaBDE, the following chemicals met the criteria for Potentially Problematic:

- DecaBDE: Moderate Concern for developmental neurological effects; pre-cancerous liver lesions but at very high dose, cancer risk likely low; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include two-generation reproductive/developmental and neurological effects studies; concerns about breakdown products (as discussed in Section 3.1).
- Triphenyl phosphate: High Concern for acute and chronic aquatic toxicity (very wide range of fish lethality levels); Low Concern for other effects based on existing data and professional judgment; key data deficiencies include cancer and two-generation reproductive/developmental studies.
- Tricresyl phosphate: High Concern for acute and chronic toxicity to fish; No Concern for cancer risk; no data for local effects; Low Concern for other effects based on existing data and professional judgment; key data deficiencies include skin and eye irritation and two-generation reproductive/development studies.
- Diphenyl cresyl phosphate: Moderate Concern for aquatic toxicity and no data for fish chronic toxicity; Moderate Concern for skin irritation and no eye irritation data; Low Concern for other effects based on existing data and professional

- judgment; key data deficiencies include cancer, two-generation reproductive/developmental, eye irritation, and fish chronic toxicity studies.
- Tetrakis(hydroxymethyl) phosphonium chloride: High Concern for acute and chronic toxicity to algae; Moderate/High Concern for local effects (skin irritant and sensitizer, but test with humans shows treated fabric not irritating to skin, and severe eye irritant); No Concern for cancer risk; Moderate Concern for systemic toxicity for liver and neurological effects; Low Concern for other effects; miscible with water, potential risks to groundwater; key data deficiency is two-generation reproductive/developmental study.
  - Antimony trioxide: High Concern for blood effects; Moderate Concern for cancer and lung irritation effects; no data for reproductive/developmental and neurological effects; Low Concern for other effects; key data deficiencies include additional cancer studies, and reproductive/developmental and neurological effects studies.
  - Boron compounds (borates other than Zinc borate): Moderate Concern for reproductive/developmental effects based on testicular and developmental effects; Moderate Concern for skin and eye irritation; no data for cancer and chronic aquatic toxicity, Low Concern for other effects; key data deficiencies include cancer, skin sensitization, and chronic aquatic toxicity studies.

Insufficient Data – In our opinion, the following chemicals’ databases are insufficient to allow us to place the chemical in any of the other bins:

- Diethylphosphinic acid, aluminum salt: Low Concern for local effects and acute environmental toxicity; insufficient data for all other effects; key data deficiencies include cancer, reproductive/developmental, and systemic effects studies, and environmental fate data.
- Melamine: Bladder tumors found in male mice and rats at very high doses and only when bladder stones present (potentially not related to melamine but may be a general response to a foreign substance), cancer risk may be low; No Concern for environmental effects; insufficient data for other effects; key data deficiencies include additional cancer studies, reproductive/developmental, neurotoxicity, and immunotoxicity studies.
- Red phosphorus: High Concern for acute aquatic toxicity; probably Low Concern for local effects but no skin sensitization data available; insufficient data for all other effects; key data deficiencies include cancer, reproductive/developmental, systemic effects, and chronic aquatic toxicity studies.
- Ammonium polyphosphates: probably Low Concern for acute environmental toxicity (no terrestrial data but rapid breakdown to ammonia and phosphate should produce relatively low toxicity); no data for other endpoints, although toxicities of ammonia and phosphate are low for most effects.

Not Recommended – The following chemicals are not recommended as potential alternatives to DecaBDE due to serious health and/or environmental concerns:

- Polytetrafluoroethylene: High Concern for known respiratory effects of toxic thermal degradation products; Moderate Concern for cancer effects, although finding of tumors only in areas of implanted Polytetrafluoroethylene raises doubt about relevance to human cancer risk from use as a flame retardant; High Concern for lung irritation when heated; no data available for reproductive/developmental effects and acute and chronic aquatic toxicity; bird mortalities reported from overheated Teflon cookware.
- Zinc borate: High Concern for effects on blood; High Concern for acute aquatic toxicity; no data for cancer, reproductive/developmental effects, and chronic aquatic toxicity.

This report should not be considered the Agency's final word regarding alternatives to DecaBDE's uses. These evaluations of selected alternatives are presented so that the reader may have an idea of the relative human and environmental concerns at this time for the most used or most likely alternatives. We have also identified current data gaps so that the reader may be aware of the uncertainties associated with the alternatives. Our evaluations would likely change over time as additional chemicals surface as important alternatives, and as studies become available to fill the data needs of the chemicals included in this evaluation.

These evaluations are intended to help inform the selection of DecaBDE alternatives by industries wishing to phase out DecaBDE from their products. They might also be used by the General Assembly should it choose to help manage the phase-out of DecaBDE. However, the many uses of DecaBDE and the many available alternatives dictate that the ultimate selection of an alternative is a complicated process, as illustrated in the next appendix, and management of the replacement process will be equally complicated.

RATING SCHEME FOR HUMAN AND ENVIRONMENTAL EFFECTS OF DECA-BDE ALTERNATIVES.

ENDPOINT	LEVEL OF CONCERN FOR ENDPOINT			
	HIGH	MODERATE	LOW	NO
Cancer	“Known or Probable” Classification by Authorities	“Possible” Classification by Authorities	Insufficient Data, Professional Judgment (a)	No Evidence in Adequate Test
Reproductive/Developmental	Human Data; clear evidence in animal study including 2-generation test	Evidence from animal studies but no 2- generation test	Evidence from animal studies but at high doses; no evidence in adequate test but no 2- generation test	No evidence in adequate tests including 2-generation test
Systemic Toxicity	Human data; animal data at doses <1 mg/kg/d	Animal data at moderate doses (1-10 mg/kg/d); profess- ional judgment (a)	Animal data at moderate doses (10-100 mg/kg/d); professional judgment (a)	Human data; animal data at doses > 100 mg/kg/d
Local Effects	Positive sensitization test; severe skin, eye irritation	Moderate skin, eye irritation, and negative sensitization test	Low skin, eye irritation; professional judgment (a)	No skin, eye irritation, and negative sensitization test
Acute Environmental Effects	LC <sub>50</sub> < 1mg/l; LD <sub>50</sub> < 5mg/kg	LC <sub>50</sub> =1-10 mg/l; LD <sub>50</sub> =5-50 mg/kg	LC <sub>50</sub> =10-100 mg/l; LD <sub>50</sub> =50-500 mg/kg	LC <sub>50</sub> > 100 mg/l; LD <sub>50</sub> > 500 mg/kg
Chronic Environmental Effects	NOEC/LOEC < 0.01 mg/l	NOEC/LOEC= 0.01- 0.1 mg/l	NOEC/LOEC= 0.1-1.0 mg/l	NOEC/LOEC>1.0mg/l
Persistent, Bioaccumulative, and Toxic	P=Half Life ≥ 60d B= BCF ≥ 5000; K <sub>ow</sub> ≥ 5 T= LC <sub>50</sub> < 1mg/l; NOEC/LOEC <0.1mg/l	Professional Judgment (a)	Professional Judgment (a)	P=Half Life < 60d B= BCF < 5000; K <sub>ow</sub> < 5 T= LC <sub>50</sub> > 1mg/l; NOEC/LOEC >0.1mg/l

Notes:

(a) Professional Judgment includes data from surrogate chemicals, structure-activity relationships, and non-peer reviewed studies, and human experience.

LC<sub>50</sub>= Water concentration lethal to 50% of an aquatic species

LD<sub>50</sub>= Dose lethal to 50% of a terrestrial species

NOEC= No effects concentration in chronic tests from aquatic species

LOEC= Lowest effects concentration in chronic tests from aquatic species

Half-Life= Time for disappearance of one-half the initial concentration of a chemical in soil, water, or air

BCF= Bioconcentration factor

K<sub>ow</sub>= Organic carbon partition co-efficient

ATTACHMENT: SCORING SUMMARIES FOR DECA-BDE AND  
ALTERNATIVES

Note: The following abbreviations are employed in the Scoring Summaries.

BCF= Bioconcentration Factor

EC-50= Water concentration at which 50% of test organisms exhibit a response

Kow= Organic carbon partition coefficient

LC-50= Water concentration lethal to 50% of an aquatic species

LD-50= Dose lethal to 50% of a terrestrial species

LOAEL= Lowest observable adverse effect level for a terrestrial species

LOEC= Lowest observable effects concentration for aquatic species

NOAEL= No observable adverse effects level for a terrestrial species

NOEC= No observable effects concentration for aquatic species

PBT= Persistent, Bioaccumulative, and Toxic

t-1/2= half-life; time for disappearance of one-half the initial concentration of a chemical  
in soil, water, or air

**CHEMICAL:** Decabromodiphenyl ether (DecaBDE); CAS# 1163-19-5

### **Toxicity Score**

**Cancer:** Some evidence (pre-cancerous liver lesions at very high dose); not mutagenic (3 assays); no chromosomal abnormalities (1 assay); Score=Insufficient Data, but human cancer risk likely Low Concern.

**Reproductive/developmental effects:** NOAEL for reproductive effects=100 mg/kg/d (highest dose tested); LOAEL for developmental neurotoxic effects=2.22 mg/kg, but study has been criticized; Score=Insufficient Data, no evidence of reproductive risk but no 2-generation study, insufficient data for developmental risks; concern about breakdown products.

**Systemic toxicity:** 28-day LOAEL for liver effects=90 mg/kg/d; 2-year LOAEL for thyroid effects=3200 mg/kg/d, but some evidence for effects at lower doses; Score=Insufficient Data, low concern for liver effects, but insufficient data for neurotoxic effects; concern about breakdown products; human risks likely Low or Moderate Concern.

**Local effects:** No skin or eye irritation; not a sensitizer; Score=No Concern.

### **Environmental Score**

**Acute toxicity:** Rat LD-50>2000 mg/kg; algal inhibition EC-50>1 mg/l; fish LC-50 exceeds solubility; Score=Low Concern.

**Chronic toxicity:** Fish LOEC=7.5-10 mg/l; Daphnia reproduction NOEC exceeds solubility; Score=Low Concern.

**PBT:** Log Kow=5.24, 6.27, Bioaccumulative; t<sub>1/2</sub> in water=180 days, Persistent; Low Concern for toxicity, but concern about breakdown products; Score= not a PBT chemical.

**Overall Score:** Potentially Problematic, due to developmental neurotoxic effects, concern for breakdown products.



**CHEMICAL:** Bisphenol A diphenyl phosphate (BAPP); CAS# 181028-79-5

**Toxicity Score**

**Cancer:** No cancer data; not mutagenic (3 assays); no chromosomal abnormalities (1 assay); Score=Insufficient Data, but human cancer risk likely Low Concern.

**Reproductive/developmental effects:** NOAEL for developmental effects=1000 mg/kg/d (highest dose tested); Score=Insufficient Data, no evidence of developmental risk, but no data for reproductive risks.

**Systemic toxicity:** 28-day rat NOAELs=1000 mg/kg/d (highest dose tested, includes neurotoxicity evaluation), 1862 mg/kg/d (males), and 1968 mg/kg/d (females) (highest doses tested); no longer-term studies found; Score=Insufficient Data, human risks probably Low Concern.

**Local effects:** Minimal skin and eye irritation; not a sensitizer; Score=Low Concern.

**Environmental Score**

**Acute toxicity:** Rat LD-50s>2000 and 5000 mg/kg; fish and Daphnia NOECs exceed solubility; Score=Insufficient Data but probably Low Concern.

**Chronic toxicity:** Daphnia reproduction NOEC>0.02 mg/l; no fish data; Score=Insufficient Data.

**PBT:** BCF=3.16 (estimated), not Bioaccumulative; t<sub>1/2</sub> in water> 1 year, Persistent; insufficient toxicity data, Score=Insufficient Data, but probably not a PBT chemical.

**Overall Score:** Potentially Unproblematic; key data deficiencies include cancer, 2-generation reproductive/developmental effects, and chronic toxicity studies.

**CHEMICAL:** Resorcinol bis(diphenyl phosphate); CAS# 57583-54-7

**Toxicity Score**

**Cancer:** No cancer data; not mutagenic (1 assay); no chromosomal abnormalities (1 assay); Score=Insufficient Data, but human cancer risk likely Low Concern.

**Reproductive/developmental effects:** Rat 2-generation study NOAEL=20000 mg/kg/d (highest dose tested); Score=No Concern.

**Systemic toxicity:** 28-day LOAEL for increased liver weight=100 mg/kg/d (lowest dose tested); NOAEL for immune system effects=5000 mg/kg/d (highest dose tested); no other short- or long-term data; Score=Insufficient Data but human risks probably Low Concern.

**Local effects:** Minimal skin and eye irritation; not a sensitizer; Score=Low Concern.

**Environmental Score**

**Acute toxicity:** Rat LD-50>5000 mg/kg; fish LC-50=12.4 mg/l; Daphnia immobilization EC-50=0.76 mg/l; Score=Low/Moderate Concern.

**Chronic toxicity:** No data available.

**PBT:** BCFs=316 (calculated) and 3000 (estimated), not Bioaccumulative; t<sub>1/2</sub> in water=7-21 days (pH dependent), not Persistent; Score= not a PBT chemical.

**Overall Score:** Potentially Unproblematic; key data deficiencies include cancer and chronic toxicity studies.

**CHEMICAL:** Aluminum trihydroxide; CAS# 21645-51-2

### **Toxicity Score**

**Cancer:** No data available; Score=Insufficient Data, but human cancer risk likely Low Concern based on professional judgment (human exposure history from medicinal uses).

**Reproductive/developmental effects:** NOAEL for birth defects=1000 mg/kg/d (highest dose tested); no other data available; Score=Insufficient Data, but risks likely Low Concern based on professional judgment (human exposure history from medicinal uses).

**Systemic toxicity:** Lung fibrosis at high particulate concentrations; rat 28-day NOAEL=302 mg/kg/d (highest dose tested); Score=Insufficient Data, but risks likely Low Concern based on professional judgment (human exposure history from medicinal uses).

**Local effects:** No skin irritation or sensitization; aluminum trihydroxide does not irritate eyes, but aluminum particles do; Score=Low Concern.

### **Environmental Score**

**Acute toxicity:** Rat LD-50>5000 mg/kg; Daphnia LC-50=2.6-3.5 mg/l; fish lethality only at low pH; Score=Low/Moderate Concern.

**Chronic toxicity:** No data available.

**PBT:** Not toxic, no other data available; Score=Not a PBT chemical.

**Overall Score:** Potentially Unproblematic, key data deficiencies include cancer, neurological, and chronic toxicity studies.

**CHEMICAL:** Magnesium hydroxide; CAS# 1309-42-8

### **Toxicity Score**

**Cancer:** No data available; Score=Insufficient Data, but human cancer risk likely Low Concern based on professional judgment (human exposure history from food and medicinal uses).

**Reproductive/developmental effects:** No data available; Score=Insufficient Data, but human risks likely Low Concern based on professional judgment (human exposure history from food and medicinal uses).

**Systemic toxicity:** Lung effects at high particulate concentrations; central nervous system depression at very high doses; no other data available; Score=Insufficient Data, but human risks likely Low Concern based on professional judgment (human exposure history from food and medicinal uses).

**Local effects:** Prolonged contact may cause skin irritation; magnesium particles may irritate eyes; no sensitization data; Score=Low/Moderate Concern.

### **Environmental Score**

**Acute toxicity:** Rat LD-50=8500 mg/kg; invertebrate LC-50=64.7 mg/l; Score=Insufficient Data, risks likely Low Concern.

**Chronic toxicity:** No data available.

**PBT:** No data available; probably not a PBT chemical.

**Overall Score:** Potentially Unproblematic, key data deficiencies include cancer, reproductive/developmental, and chronic toxicity studies.

**CHEMICAL:** Triphenyl phosphate; CAS#115-86-6

### **Toxicity Score**

**Cancer:** No data (1 inadequate study); not mutagenic (2 assays); Score=Insufficient Data, human cancer risk likely Low Concern.

**Reproductive/developmental effects:** Rat NOAEL for developmental and birth defect effects=690 mg/kg/d (highest dose tested); Score=Insufficient Data, no evidence of reproductive/developmental effects but no 2-generation study, human risks likely Low Concern.

**Systemic toxicity:** Rat NOAEL for decreased weight gain and neurological effects=161 mg/kg/d; rat NOAEL for decreased weight gain and liver effects=1000 mg/kg/d; rat NOAEL for immune effects=700 mg/kg/d; not a delayed neurotoxicant; Score=Low Concern.

**Local effects:** No skin irritation; moderate eye irritation; no skin sensitization data; Score=Low/Moderate Concern.

### **Environmental Score**

**Acute toxicity:** Rat LD-50=3500-10800 mg/kg; algal inhibition EC-50=0.26-2.0 mg/l; Daphnia LC-50=1.0-1.2 mg/l; fish LC-50=0.36-290 mg/l; Score=High Concern.

**Chronic toxicity:** Daphnia NOEC=0.1 mg/l (estimated); fish NOEC for survival and growth=0.0014 mg/l; Score=High Concern.

**PBT:** BCF=18-2590, not Bioaccumulative;  $t_{1/2}$  in water=<5-366 days (pH dependent), Persistent at low pH; highly toxic; Score=not a PBT chemical.

**Overall Score:** Potentially Problematic (borderline), key data deficiencies include cancer and 2-generation reproductive/developmental studies.

**CHEMICAL:** Tricresyl phosphate; CAS# 1330-78-5 (commercial mixture, <2% o-cresyl isomer)

### **Toxicity Score**

**Cancer:** No evidence in rat and mouse studies; not mutagenic (3 assays); Score=No Concern.

**Reproductive/developmental effects:** Rat LOAEL for sperm effects=100 mg/kg/d; no other data available; Score=Insufficient Data, human risks possibly Low Concern.

**Systemic toxicity:** Pig LOAEL for paralysis after repeated skin exposure=128 mg/kg; rat 90-day NOAEL=1000mg/kg/d (highest dose tested); Score=Low Concern.

**Local effects:** No data available.

### **Environmental Score**

**Acute toxicity:** Rat, mouse, rabbit, chicken LD-50s>1000 mg/kg; algal inhibition EC-50=1.3-3.8 mg/l; Daphnia immobilization EC-50=3.6-9.1 mg/l; fish LC-50=0.15-13 mg/l; Score=High Concern for aquatic toxicity.

**Chronic toxicity:** Daphnia NOEC=0.1 mg/l; fish NOEC=0.00032-0.28 mg/l; Score=High Concern.

**PBT:** BCF=165-281, Log Kow=4.9-5.1 (calculated), not Bioaccumulative; t ½ in water<5 days, not Persistent; highly toxic; Score=not a PBT chemical.

**Overall Score:** Potentially Problematic, key data deficiencies include 2-generation reproductive/developmental and irritation and sensitization studies.

**CHEMICAL:** Diphenyl cresyl phosphate; CAS# 26444-49-5

### **Toxicity Score**

**Cancer:** No cancer data; not mutagenic (2 assays); no chromosomal abnormalities (1 assay); Score=Insufficient Data, human cancer risk likely Low Concern.

**Reproductive/developmental effects:** Rat NOAEL for sperm effects=60 mg/kg/d; offspring effects only at maternally toxic doses; no 2-generation study; Score=Low Concern.

**Systemic toxicity:** Chicken single-dose LOAEL for neurotoxic effects=2500 mg/kg; rat single-dose LOAEL for neurotoxic effects=75 mg/kg; rat NOAEL for adrenal effects=12 mg/kg/d; Score=Low Concern.

**Local effects:** Slight to moderate skin irritation; no eye irritation or skin sensitization data available; Score=Insufficient Data, possibly Moderate Concern.

### **Environmental Score**

**Acute toxicity:** Rat, mouse, rabbit, guinea pig LD-50s>1000 mg/kg; algal inhibition EC-50=1.0 mg/l; Daphnia immobilization EC-50=3.7 mg/l; fish LC-50=1.3 mg/l (2 other LC-50s exceed solubility); Score= Moderate Concern for aquatic toxicity.

**Chronic toxicity:** Algal inhibition NOEC=0.55 mg/l; Daphnia NOEC=0.12 mg/l; no fish data; Score=Insufficient Data, possibly Moderate Concern.

**PBT:** BCF=360-980 (calculated), Log Kow=4.51, not Bioaccumulative; t<sub>1/2</sub> in water=38 days, not Persistent; moderately toxic; Score=not a PBT chemical.

**Overall Score:** Potentially Problematic, key data deficiencies include cancer, 2-generation reproductive/developmental, eye irritation, skin sensitization, and fish NOEC studies.

**CHEMICAL:** Tetrakis(hydroxymethyl) phosphonium chloride; CAS#124-64-1

### **Toxicity Score**

**Cancer:** No evidence in rat and mouse studies; mutagenic in 1 assay, negative in 3 assays, equivocal evidence in 2 assays; Score= No Concern.

**Reproductive/developmental effects:** Offspring effects only at maternally toxic doses in rats and rabbits; no 2-generation study; Score=Low Concern

**Systemic toxicity:** Rat and mouse 13-week NOAEL for neurotoxic effects=2.7 and 3.2 mg/kg/d; rat and mouse chronic LOAEL for liver and neurotoxic effects=3.75 and 7.5 mg/kg/d; Score=Moderate Concern.

**Local effects:** Moderate skin irritation; severe eye irritation; skin sensitizer; Score=Moderate/High Concern (treated fabric found not irritating to human skin).

### **Environmental Score**

**Acute toxicity:** Rat, mouse, duck LD-50s>150 mg/kg; algal inhibition EC-50=0.16-0.65 mg/l; Daphnia LC-50=19.4 mg/l; fish LC-50=72-119 mg/l; Score=High Concern.

**Chronic toxicity:** Algal inhibition NOEC=0.06 mg/l; Daphnia NOEC=10.4 mg/l; fish NOEC=18.1-22.7 mg/l; Score=High Concern.

**PBT:** Log Kow=-9.8 (calculated), not Bioaccumulative; t<sub>1/2</sub> in water=7-131 days (pH dependent), Persistent at low pH; highly toxic; Score=not a PBT chemical.

**Overall Score:** Potentially Problematic, miscible in water and very low Kow so highly mobile in soil; key data deficiency is 2-generation reproductive/developmental effects study.



**CHEMICAL:** Antimony trioxide; CAS# 1309-64-4

**Toxicity Score**

**Cancer:** Conflicting data regarding lung tumors, ranked possible carcinogen by IARC; Score=Moderate Concern.

**Reproductive/developmental effects:** No usable data (inhalation study at high concentrations inconclusive); Score=Insufficient Data.

**Systemic toxicity:** Rat 90-day NOAEL=494 mg/kg/d and 24-week LOAEL=500mg/kg/d (lowest dose tested) for liver effects; rat chronic LOAEL for blood effects=0.35 mg/kg/d (lowest dose tested); Score=High Concern.

**Local effects:** No skin irritation or sensitization; contact with eyes causes conjunctivitis; NOAEL for lung irritation and fibrosis=0.042 mg/m<sup>3</sup>; Score=Moderate Concern.

**Environmental Score**

**Acute toxicity:** Rat LD-50>20000 and >34600 mg/kg; algal inhibition EC-50=67 mg/l; Daphnia LC-50>530 mg/l; fish LC-50>440 and >1000 mg/l; Score=Low Concern.

**Chronic toxicity:** Algal inhibition NOEC=0.20 mg/l; no other data available; Score=Insufficient Data, probably Low/Moderate Concern.

**PBT:** No data available; probably not a PBT chemical.

**Overall Score:** Potentially Problematic, key data deficiencies include cancer, reproductive/developmental effects, and neurotoxicity studies.

**CHEMICAL:** Boron compounds other than Zinc borate; CAS#s 10043-35-3 (Boric acid), 1303-96-4 (Borax=Sodium borate decahydrate), 1330-43-4 (Disodium tetraborate)

### **Toxicity Score**

**Cancer:** No data available.

**Reproductive/developmental effects:** IRIS Benchmark Dose for developmental effects=10.3 mg/kg/d; rat NOAEL for testis effects=175 mg/kg in diet; rabbit NOAEL for birth defects=125 mg/kg/d; no 2-generation study; Score=Moderate Concern.

**Systemic toxicity:** Rat and dog chronic NOAEL for multiple effects=350 mg/kg in diet; Score=Low Concern.

**Local effects:** Mild to moderate skin irritation; mild eye irritation; Score=Moderate Concern.

### **Environmental Score**

**Acute toxicity:** Rat, mouse, dog LD-50>2000 mg/kg; fish LC-50>15 mg/l; Score=Low Concern.

**Chronic toxicity:** No data available.

**PBT:** No data available, probably not a PBT chemical.

**Overall Score:** Potentially Problematic, key data deficiencies include cancer, 2-generation reproductive/developmental effects, and chronic aquatic toxicity studies.

**CHEMICAL:** Diethylphosphinic acid, aluminum salt; CAS#225789-38-8

**Toxicity Score**

**Cancer:** No cancer data available; not mutagenic (1 assay); no chromosomal abnormalities (1 assay); Score=Insufficient Data.

**Reproductive/developmental effects:** No data available.

**Systemic toxicity:** Rat NOAEL=1000 mg/kg/d (highest dose tested); no other data available; Score=Insufficient Data.

**Local effects:** No skin irritation; slight eye irritation; not a sensitizer; Score=Low Concern.

**Environmental Score**

**Acute toxicity:** Rat LD-50>2000 mg/kg/d; Daphnia and fish LC-50s exceed water solubility; Score=Low Concern.

**Chronic toxicity:** Algal inhibition NOEC exceeds water solubility; Daphnia NOEC=1-10 mg/l; no fish data available; Score=Insufficient Data.

**PBT:** Log Kow=-0.44 (estimated), not Bioaccumulative; no t ½ data available; not a PBT chemical.

**Overall Score:** Insufficient Data, key data deficiencies include cancer, reproductive/developmental effects, systemic toxicity, and environmental fate studies.

**CHEMICAL:** Melamine; CAS# 108-78-1, Melamine cyanurate; CAS# 37640-57-6

### **Toxicity Score**

**Cancer:** Bladder tumors in male mice and rats, but only at high doses and only when bladder stones present (possibly a general response to a foreign substance and not compound-related); not mutagenic (5 assays); no chromosomal abnormalities (2 assays); ranked not classifiable by IARC; Score=Low Concern.

**Reproductive/developmental effects:** Rat and mouse chronic NOAEL for histological effects=63 mg/kg/d; rat NOAEL for birth defects=70 mg/kg; no other data available; Score=Insufficient Data.

**Systemic toxicity:** Rat LOAEL for decreased weight gain=500 mg/kg/d; dog NOAEL for decreased weight gain=3000 mg/kg in diet; rat 13-week NOAEL for bladder stone formation=63 mg/kg/d; no other data available; Score=Insufficient Data.

**Local effects:** Allergic dermatitis reported in workers, but no skin irritation in guinea pigs; no eye irritation; not a sensitizer; Score=Low/Moderate Concern.

### **Environmental Score**

**Acute toxicity:** Rat and mouse LD-50s>3000 mg/kg; algal inhibition EC-50=940 mg/l; Daphnia EC-50>2000 mg/l; fish LC-50s>50, >500, >3000 mg/l; Score=No Concern.

**Chronic toxicity:** Algal inhibition NOEC=320 mg/l; Daphnia NOEC=18 mg/l; fish NOEC>10000 mg/l; Score=No Concern.

**PBT:** Log Kow=-1.14, -1.34, not Bioaccumulative; no half-life data available; not toxic; Score=not a PBT chemical.

**Overall Score:** Insufficient Data, key data deficiencies include additional cancer, reproductive/developmental effects, neurological effects, and immune effects studies.

**CHEMICAL:** Red phosphorus; CAS# 7723-14-0

**Toxicity Score**

**Cancer:** No data available.

**Reproductive/developmental effects:** No data available.

**Systemic toxicity:** Lung damage in rats, mice, and guinea pigs from high concentrations of red phosphorus smoke; no other data available; Score=Insufficient Data.

**Local effects:** No skin or eye irritation; no skin sensitization data available; Score=Insufficient Data, human risk probably Low Concern.

**Environmental Score**

**Acute toxicity:** Rat LD-50>15000 mg/kg; algal inhibition EC-50=1.3 mg/l; Daphnia EC-50=0.63 mg/l; fish LC-50=0.95 mg/l; Score=High Concern.

**Chronic toxicity:** No data available.

**PBT:** No BCF or half-life data available; highly toxic; Score=Insufficient Data, but probably not a PBT chemical.

**Overall Score:** Insufficient Data, key data deficiencies include cancer, reproductive/developmental effects, systemic toxicity, and chronic aquatic toxicity studies.

**CHEMICAL:** Ammonium polyphosphate; CAS# 68333-79-9

**Toxicity Score**

**Cancer:** No data available; readily breaks down to ammonia and phosphate; Score=Insufficient Data, human cancer risk may be Low Concern.

**Reproductive/developmental effects:** No data available; readily breaks down to ammonia and phosphate; Score=Insufficient Data, human risk may be Low Concern.

**Systemic toxicity:** No data available; readily breaks down to ammonia and phosphate; Score=Insufficient Data, human risk may be Low Concern.

**Local effects:** No data available.

**Environmental Score**

**Acute toxicity:** No animal LD-50 data available; algal inhibition EC-50=10 mg/l; Daphnia EC-50=91-100 mg/l; fish LC-50=123 mg/l (ph=8), 1326 mg/l (pH=7); Score=Low Concern.

**Chronic toxicity:** No data available.

**PBT:** No BCF or half-life data available; probably not highly toxic; Score=Insufficient Data, probably not a PBT chemical.

**Overall Score:** Insufficient Data, key data deficiencies include cancer, reproductive/developmental effects, systemic toxicity, local effects, and chronic aquatic toxicity studies.

**CHEMICAL:** Polytetrafluoroethylene (Teflon); CAS# 9002-84-0

**Toxicity Score**

**Cancer:** Tumors found at site of implant questionable for evaluating human cancer risk from use as flame retardant; ranked not classifiable by IARC; Score=Moderate Concern.

**Reproductive/developmental effects:** No data available.

**Systemic toxicity:** Rat 90-day NOAEL=250000 mg/kg in diet (highest dose tested); Score=No Concern.

**Local effects:** No skin irritation; no eye irritation data available; not a sensitizer; highly irritating to lungs when heated; Score=High Concern.

**Environmental Score**

**Acute toxicity:** No data available; bird lethality found in cases of overheated Teflon cookware; Score=Insufficient Data.

**Chronic toxicity:** No data available.

**PBT:** Polymer, not applicable.

**Overall Score:** Not Recommended, due to high concern for thermal breakdown products.

**CHEMICAL:** Zinc borate; CAS# 1332-07-6

**Toxicity Score**

**Cancer:** No cancer data available; not mutagenic (1 assay); Score=Insufficient Data.

**Reproductive/developmental effects:** No data available.

**Systemic toxicity:** Human LOAEL for zinc for blood effects=0.91 mg/kg/d; no other data available; Score=High Concern based on zinc toxicity.

**Local effects:** No skin irritation; mild eye irritation; not a sensitizer; nose and throat irritation from inhalation of dust; Score=Moderate Concern.

**Environmental Score**

**Acute toxicity:** Rat, mouse, dog LD-50s>2000 mg/kg; algal inhibition EC-50=0.015-0.178 mg/l; Daphnia EC-50=0.068-1.59 mg/l; fish LC-50=0.59-5.9 mg/l; Score=High Concern.

**Chronic toxicity:** No data available.

**PBT:** No BCF or half-life data available; highly toxic; Score=Insufficient Data, but probably not a PBT chemical.

**Overall Score:** Not Recommended, due to High Concern for blood effects and aquatic toxicity.



## **REFERENCES FOR APPENDIX III: TOXICITY EVALUATION OF ALTERNATIVES**

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## APPENDIX IV OVERVIEW AND DISCUSSION OF AFFORDABILITY AND AVAILABILITY ISSUES

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### Introduction and Overall Conclusions on Affordability

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As mentioned earlier in this report, the purpose of this follow-up study is to determine if alternatives to DecaBDE are available, affordable, and less toxic. This appendix addresses primarily **affordability issues**. Discussions of affordability issues, as they

**The halogen-free [Deca has bromine halogens] flame retardants market will increase from 1.62 billion in 2005 to 2.72 billion in 2010 worldwide. Halogen-free flame retardants will show this strong increase worldwide. In Western Europe, USA and Japan, the public consciousness of the hazardous halogenated products, the industrial end user [OEMs] initiatives and the environmental legislation push together the market trend to halogen-free products.<sup>1</sup>**

relate to alternatives to DecaBDE flame retardants (FRs), are complex because issues relate to a global market.

Industries in Illinois, as well as other states, that participate in global markets must adhere to a wide variety of economic and environmental requirements, including those regulating flame retardants like DecaBDE.

However, we note that a wide variety of

industries have already recognized the need to replace DecaBDE. There is no uniform phase-out approach and each industry sector is at a different stage in the task of accomplishing the transition away from DecaBDE.

Our overall **affordability conclusion**, based on verbal communications with trade groups, contacts with companies at all levels (see the listing of organizations contacted during this review at the end of this appendix), a review of PBDE related issues at industry/company websites, and a review of general internet articles on PBDE issues is:

■ There are sufficient, affordable, alternative flame retardants available for all DecaBDE applications across all industries, however, there is a significant amount of laboratory testing to be performed before all products using DecaBDE alternatives can be introduced into the marketplace. A key affordability issue relates to providing a mechanism in Illinois that allows for a managed and flexible phase-out approach for completing the transition away from DecaBDE that provides sufficient time to complete the extensive laboratory testing to verify product performance and fire safety, especially in the transportation and medical device industries.

**Converting products to RoHS [European Legislation restricting PBDEs octa and penta with deca still under review] compliance may take a one-time investment [by increasing product costs] of 1.5% to 2.5% of a product's cost of goods sold, but in the past 30 years many industries have had to account for product content (gasoline, packaged food, apparel, wood products, chemical, etc) and today are just as profitable or more profitable than ever.<sup>2</sup>**

## Affordability By Industry

A summary of the affordability issues in each major industry group using flame retardants follows:

- ➔ **Consumer electronics** including computers, televisions, cell phones
  - **No significant affordability issues** here, transition away from DecaBDE is substantially complete. Any remaining products with DecaBDE are in the final stages of transition to affordable alternative flame retardants. A small percentage of companies may need some additional time to complete laboratory work for product/performance testing and fire safety.

- ➔ **Other electronics applications** mainly cable/wiring (including construction/building applications) and electronic assemblies using cable/wiring/plastics.
  - **Minimal affordability issues** here, transition away from DecaBDE is substantially complete, affordable DecaBDE alternatives available and most items are in their final stages of transition. Many “green” products are mentioned on the wire/cable industry websites. Some additional, minimal product performance testing may still be required to complete the transition.

- ➔ **Medical Devices**
  - **Moderate affordability issues** due to extensive product testing requirements in this industry. The Electronic Industry Alliance (EIA) and GE Healthcare confirmed the need for additional product performance and safety testing for DecaBDE alternatives. Requirements for electrical safety of medical equipment are much more stringent than those for other electrical devices and must meet International Electrotechnical Commission (IEC) safety standard (IEC and UL 60601-1).

The Lowell Center report estimated that the average television may go up in price 1.5 to 2.5 percent or an increase in price around \$7.00 due to the FR change.<sup>3</sup>

- ➔ **Textile and Foam**
  - **Moderate affordability issues** here and only in the **transportation** industry. PBDE, including DecaBDE, flame retardants in residential products (furniture) and office products (furniture, cubicle walls) are no longer used. There are many different flame retardants, fibers, and barrier substitutes to meet the demand for DecaBDE free products that meet strict fire safety standards.<sup>4</sup> However, use of DecaBDE in fabrics for transportation applications such as automobiles, recreational vehicles, and airliners has **significant affordability issues at this time** and these issues relate primarily to regulatory required product performance and flammability testing.

➔ **Transportation (airline, automotive, and recreational vehicles)**

- **Significant affordability issues** at this time. Some companies in these industries have a significant level of testing and laboratory work yet to perform on potential alternatives to DecaBDE. DecaBDE is in plastics, electrical wiring, electronic components, fuel systems, and upholstery. The alternatives have been developed by the chemical industry and the associated component/parts industry. However, incorporating the DecaBDE alternatives into final products (airliners, automobiles, RVs) will take several years to complete due to required product quality/performance testing and associated laboratory work to verify fire safety. Some transportation companies, however, have made substantial progress. For example, Illinois-based company Mitsubishi (auto manufacturer located in Bloomington/Normal Illinois) stated that a requirement to use DecaBDE alternatives “will have little impact on cost” since their suppliers had already engineered DecaBDE out of their products.

Highlights and information on the status of the transition away from DecaBDE in each major industry group are illustrated at the end of this appendix.

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**Industry-wide Marketplace Pressures Are Causing An Affordable Transition Away From PBDEs/DecaBDE Flame Retardants**

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**Overview of Marketplace Pressures**

Market participants involving flame retardants like DecaBDE involve a wide variety of companies at different levels of the supply chain including the following types:

- Chemical manufacturers that produce flame retardants like DecaBDE,
- Parts/component manufacturers and suppliers (wiring/cable, replacement parts),
- Consumer product manufactures often referred to as Original Equipment Manufactures (OEMs) like Hewlett Packard, Dell, Panasonic, Mitsubishi
- A variety of retailers that sell consumer products potentially containing DecaBDE like Wal-Mart.

The global market for “green” materials is estimated at \$6.1 billion in 2005 and is estimated at \$8.7 billion by 2010 and PBB and PBDE replacements represent the largest share of this market.<sup>5</sup>

All of the above market participants involved in the supply chain of products with flame retardants have made significant progress to ensure that processes, products, and policies all contribute to the removal of DecaBDE from products throughout the supply/product chain.

The market for flame retardants is experiencing an internal conversion; the more traditional, halogenated flame retardants are slowly but surely being replaced by non-halogenated alternatives. Nowhere is this shift more pronounced than in plastics used for electronics ...Two factors are key in driving this substitution: legislative pressure and the corporate image of original equipment manufacturers (OEMs)<sup>6</sup>

A review of consumer products manufacturers websites (OEMs), communication with individual manufacturers/retailers, and contacts with industry trade groups confirms that industries and retailers involved in the

manufacture or sale of products involving flame retardants have completed or have substantially initiated the transition to DecaBDE alternatives (see details at the end of this appendix). For example, industries including electronics (televisions, computers, wire/cable etc.), medical devices, furniture, and transportation (automobile, airlines) have all taken or initiated action to transition away from PBDE based flame retardants including DecaBDE. The financial/affordability risks appear to be **higher** for companies that are **not timely transitioning away** from DecaBDE flame retardants than for those companies that have invested funds to make the transition.

Primary market risks for not transitioning away from DecaBDE include loss of market share, loss of green product sales, and a strong potential risk from negative publicity from consumer and environmental groups due to continued use of DecaBDE. From a financial, market based perspective, the discussion among chemical industry and environmental/health groups about the perceived or actual environmental and health risks of DecaBDE is no longer relevant because industries have already responded to the potential risks by transitioning away from DecaBDE. Legislation banning or looking to ban DecaBDE and consumer and OEM sentiment are now the primary driving forces to transition away from these flame retardants.

**Manufacturers of electrical and electronic products are extremely concerned with presenting a caring, environmentally friendly corporate image and have adopted a very precautionary attitude to hazardous chemicals in their products. OEMS Sony, Phillips, Dell, and Electrolux have their own restricted material programs which include lists of chemicals not officially outlawed by any regulatory body, including PBDEs like DecaBDE.<sup>7</sup>**

In discussions with several manufacturers and trade groups, some agreed that health reports identifying PBDEs in mother's milk was a primary driving force in the search for alternatives for PBDEs like DecaBDE. The market and consumer pressures generated from this fact are enormous, and in our opinion, financially insurmountable especially for OEMs. OEMs that are more concerned about their brand image are avoiding possible litigation and are opting for non-brominated FRs.<sup>8</sup>

The combined impact of increased market demand for "green" products, which requires elimination of brominated flame retardants (BFRs), and emerging regulations requiring phasing out of PBDEs, has caused all major industries using PBDEs in flame retardants to initiate action to eliminate DecaBDE and replace it with affordable alternatives. **The FR chemical and bromine industry's discussions on the safety and effectiveness of DecaBDE are not substantially affecting the transition away from DecaBDE because OEMs are listening to their consumer groups.** The Hewlett Packard website provides the best example of how OEM's and their customers are the driving forces away from brominated flame retardants like DecaBDE; the HP site states:

- "Customers sometimes encourage us to replace materials in our products. An example is the flame retardant Tetrabromobisphenol A (TBBPA). Although the World Health Organization (WHO) concluded after a full scientific assessment that TBBPA poses no significant risk to the general population and has little potential for bio-accumulation, many HP customers requested that we use alternative flame retardants. As a result, HP removed TBBPA from case plastics in a majority of our

products more than ten years ago. We have a goal to remove the remaining brominated flame retardants (BFRs), including TBBPA, from external case parts in all new HP products introduced after December 31, 2006”.<sup>9</sup>

As mentioned earlier in this report, DecaBDE is a brominated flame retardant as is TBBPA mentioned by HP above.

Another electronic manufacturer, Dell Corporation, has also created a list of banned/restricted substances for its products. It includes: “Polybrominated Biphenyls PBBs & their Ethers/Oxides (PBDEs, PBBEs), **including DecaBDE** [emphasis added].”<sup>10</sup>

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### **International Regulations Affecting the Transition From DecaBDE**

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In today’s global economy, most products that contain flame retardants are sold on the world market and products must comply with several international initiatives regulating certain chemicals. All major industries using PBDEs for flame retardants have completed or initiated actions to develop and use alternative flame retardants to PBDE based flame retardants, including DecaBDE. The primary European legislative directives are:

**Electronics Industry Alliance (EIA): “In addition to legislation, voluntary market drivers are pressuring electronic manufacturers to eliminate chemicals of concern from electronic products”.<sup>11</sup>**

- European **R**estriction of **H**azardous **S**ubstances (**RoHS**)
- European **W**aste from **E**lectrical and **E**lectronic **E**quipment (**WEEE**)

The RoHS directive deals with the types of materials and chemicals used in the manufacturing of products and restricts the use of lead, mercury, cadmium, hexavalent chromium, and certain brominated flame retardants. However, the RoHS initiative at this time has not formally banned DecaBDE but it continues to be assessed and reviewed.<sup>14</sup> The WEEE directive addresses end-of-life management of electrical and electronic equipment (e.g., take-back and recycling of used computers and equipment), including the costly separation and recovery of brominated flame retardants during the recycling process.

Both European directives have significantly increased the speed of the transition away from brominated FRs, including companies operating in the United States. Facing restrictions on PBDE use in the European Union, many U.S. manufacturers moved to find alternatives to PBDEs, even in the absence of national regulation.

Electronics industry articles and websites contain many references to the affects of the RoHS and WEEE directives including: “Global political pressures will force product designers and manufacturers in the United States to adopt more environmentally friendly designs, giving greater consideration to recycling and avoiding plastics with potentially toxic materials such as brominated flame retardants.” “A rush of legislation in Europe



and Japan, and some similar plans in China, will wind up setting de facto standards that must be met by global manufacturers.”<sup>13</sup> “While Deca-brominated chemicals are still allowed in many of the legislative initiatives, many companies are moving away from that class of chemicals altogether...”<sup>14</sup>

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### **Chemical Industry Has Already Responded to Market Pressures and Developed Affordable Alternative Flame Retardants to DecaBDE**

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A review of the chemical industry websites and related chemical industry literature, i.e. industry marketing reports, indicates that the chemical industry has already taken significant action to develop FRs to allow for the affordable transition away from PBDEs like DecaBDE. While the development of new non-halogenated FRs can add some additional costs, competition in the FR industry is significant and this competition helps to control disproportionate cost increases that would raise consumer prices.

Some examples of information on chemical industry activities relating to the transition away from PBDEs includes the following:

- Chemical company Supresta opened a new research and development laboratory in Germany in September 2006 for flame retardants. The R&D focuses on new processes to reduce manufacturing costs and the development of new products and application resulting from the trends in legislation.<sup>15</sup>
- Chemical industry marketing experts highlight that substitution of halogenated flame retardants is offering opportunities for established [chemical] market participants and new market entrants alike. Established flame retardant producers which want to maintain their strong position in this market need to re-evaluate their product-portfolios and focus their R&D efforts on developing alternative flame retardant solutions with a favorable cost/performance ratio.<sup>16</sup>
- Recent patent and technical works indicate a growing interest in halogen-free solutions with the predominance of the literature focusing on phosphorous-based flame retardants.<sup>17</sup>
- A major challenge for [flame retardant chemical industry] participants will be to provide end-product manufacturers with cost-effective flame retardant additives that are both halogen free and environment friendly. Collaborative R&D initiatives with product manufacturers will help flame retardant chemical developers design innovative products for existing applications ....This will help satisfy customer requirements even while helping them sustain their business in the competitive market.<sup>19</sup>

**Some manufacturers who believe they have seen the writing on the wall have been moving away from the use of brominated flame retardants in favor of non-halogenated solutions.<sup>18</sup>**

- Albermarle Inc., a major producer of flame retardant chemicals, stated in their Securities and Exchange Commission filing that “...there has been increased

scrutiny by regulatory authorities and environmental interest groups of polybrominated diphenylethers, or PBDEs...We manufacture decabrom-PDE...In 2005, our net sales of decabromPDE were less than 3% of total net sales.<sup>20</sup>

- Many of the chemical alternatives to DecaBDE highlighted in this report are already being sold by the chemical industry. For example, meeting notes from the State of Washington's PBDE Deca-Alternatives Advisory Committee, 11/9/2005 states: "one member commented that she spoke with the chemical companies about Deca alternatives and they indicated that the market is moving toward phosphorous-based flame retardants. She asked Health if they know which alternatives are actually being used. Health and other committee members responded that **Resorcinol bis diphenylphosphate (RDP), Bisphenol A diphosphate (BAPP), Bisphenol A bisphenylphosphate (BDP) and Triphenyl phosphate (TPP) are actually used.**<sup>21</sup>

## **HIGHLIGHTS OF DECA-BDE TRANSITION ACTIVITY FOR MAJOR INDUSTRY GROUPS (including groups contacted)**

### **Industry Specific Status and Overview Regarding Transition Away From PBDEs/Deca**

The extent that industry has completed the transition to affordable alternatives to DecaBDE into their product lines varies depending on the industry and this is discussed below. The following sections provide an overview of industry highlights and specific issues relating to where the industry groups appear to be relative to transitioning away from PBDEs including DecaBDE.

Our research of affordability issues included the following types of reviews and contacts. Contact with companies doing business in Illinois including:

- ★ Wal-Mart
- ★ Verlo Mattress Factory
- ★ Ashley Furniture and their suppliers of textiles and foam including Carpenter Company
- ★ Boeing-They confirmed that Illinois has companies that supply parts to Boeing that may contain DecaBDE.
- ★ Mitsubishi
- ★ Interface Fabrics
- ★ GE Healthcare

Contacts with trade groups including:

- ★ Alliance of Automobile Manufacturers
- ★ American Chemistry Council
- ★ American Home Furnishings Alliance
- ★ American Plastics Council
- ★ Business and Institutional Furniture Manufacturer's Association
- ★ Electronic Industries Alliance (EIA)
- ★ Medical Device Manufacturing Association

**From a review of articles, websites, and through discussions with trade associations in all industry segments appears to show transition away from PBDE should be substantially completed by year-end 2010. Some organizations may need additional time to complete laboratory testing for product performance including fire safety.**

- ★ National Electrical Manufacturers Association (NEMA)
- ★ Underwriters Laboratory
- Review of published articles and internet based information.
- Review of OEM/Company specific websites for companies such as:
  - Sony
  - Panasonic
  - Texas Instruments
  - SpecialChem Polymers
  - Hewlett Packard
  - Dell

The major categories of industry that the IEPA researched to identify available, less toxic, and affordable alternatives to DecaBDE are grouped into the following 5 industry categories below.

1. Consumer Electronics: computers, television, cell phones
2. Other Electronics/Components (e.g., cable/wiring, internal electrical components)
3. Medical Equipment
4. Textile and Foam (furniture, upholstery)
5. Transportation Industry (airline, automotive, recreational vehicles)

Except for the transportation industry, there does not appear to be **significant** affordability and timeline issues in the transformation away from DecaBDE flame retardants.

<b>1. Consumer Electronics: Computers, Televisions, Cell Phones</b>
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**There are no significant affordability issues** with the transition to DecaBDE alternatives in the consumer electronics industry.

All major participants in this industry appear to be moving away from DecaBDE. Depending on the type of electronic device, however, the degree of transition appears to vary widely. In general, the electronics industry has been reducing or eliminating brominated flame retardants since the late 1990s, when European countries began prohibiting the sale of products that contain the chemicals

- Cell phones: Transition is occurring, but a moderate level of additional time is needed as indicated by EIA as companies, such as Motorola, are still working on elimination of brominated FRs from a small number of cell phones still containing DecaBDE.
- Televisions: This appears to be one of the most challenging areas regarding transition away from PBDEs/DecaBDE. According to the Electronic Industries Alliance, the transition from PBDEs in televisions is taking longer than computers due to the thin nature of the plastics associated with televisions, alternative FRs

appear to be more difficult to incorporate into the thinner plastics; especially into the newer flat screen models. Overall, affordability issues related to transitioning to non-halogen FR systems from DecaBDE should be minimal on a per television basis due to pricing competition within the industry. While affordability is not a large issue, difficulty in transitioning from DecaBDE still requires some additional time with year-end 2010 being reasonable for completion.

- Washington State estimates that about 57% of TVs and 95% of computer products are PBDE-free”: including DecaBDE.
- According to Clean Production Action, DecaBDE has been eliminated from televisions produced by Sony, Philips, and Panasonic/Matshushita. Samsung, and LG Electronics plans to complete removal of PBDEs/DecaBDE by 2010 (11/15/06 article DecaBDE and BFR Substitution in the Electronics Industry: Leading Manufacturers are Moving Away from Bromine Chemistry in Computers and Televisions).
- A February 9, 2004 industry news statement states: Television manufacturer Philips Electronics has chosen a halogen-free flame retardant for its latest 37 inch screen model television that enables the sets to comply with certain environmental regulations and to meet strict fire safety regulation namely Underwriters Laboratories 94 V-0.
- A Dell produced document titled “Dell’s Position on Brominated Flame Retardants states: Flame-retarded plastics are occasionally needed to meet strict fire safety codes...Dell is committed to finding alternatives for the use of brominated flame retardants...We avoid brominated flame retardants by using plastics that can be flame-rated with phosphorous-based flame retardants. Since 2002, Dell has prohibited the use of brominated flame retardants (PBBs and PBDEs), including DecaBDE...”
- A Hewlett Packard news release dated November 1, 2005 stated that HP eliminated more than 95 percent of the Brominated Flame Retardants used in the external case parts of its products more than 10 years ago, including PBDE....(see HP website: [www.hp.com/hpinfo/newsroom/press/2005/051101a.html](http://www.hp.com/hpinfo/newsroom/press/2005/051101a.html))
- A Panasonic website states: Panasonic is striving to reduce our use of halogenated plastics...we have worked with other manufacturers to develop wires and plastics that do not contain halogen compounds. In September of 1999, Panasonic began marketing the world’s first wide screen TV for which halogen compounds had been eliminated from low voltage internal wires, from the cabinet, from the back cover and from a number of printed wiring boards. We are now applying this know how to a wide range of other products including laptop computers, room air conditioners, and other TVs.(see Panasonic website: [www.panasonic.com/environmental/ecodesign.asp](http://www.panasonic.com/environmental/ecodesign.asp))
- Sony’s “eco info” mark provides environmental information on their products that includes statements such as “No halogenated flame retardants are used in cabinets and

main printed wiring boards.” and “Reduction and phase-out of halogenated flame retardants”. (see <http://www.sony.net>)

- On December 19, 2006 Wal-Mart stated that they are already looking into PBDEs and that their computers and televisions are already compliant with EU environmental initiatives and that they continue to work with suppliers to eliminate hazardous chemicals from Wal-Mart products. Wal-Mart has established an electronics network made up of industry experts and academics to continue to review their products for maximum value issues including those related to the environment. Also see information on Wal-Mart at [www.turi.org/content/content/view/full/4100/](http://www.turi.org/content/content/view/full/4100/) or [www.pcimag.com/CDA/Articles/Breaking\\_News/291fc099bbfad010VgnVCM100000f932a8c0](http://www.pcimag.com/CDA/Articles/Breaking_News/291fc099bbfad010VgnVCM100000f932a8c0)
- An economist with TURI (Toxics Use Reduction Institute in Massachusetts) stated that when examining the FR related costs as a percentage of total product costs, the financial impact of an increase in costs due to a change in the flame retardant (both chemical costs and re-engineering costs) is most likely extremely small and consequently, should not significantly impact the total cost of the consumer product. For example, when comparing the costs of all of the parts and components in a computer and television with the costs of the FR changeover costs, the FR cost increases would be relatively insignificant and would have a limited impact on total product cost to the consumer.

#### **Image-conscious OEMs (taken from Frost & Sullivan Marketing Research)**

Original equipment manufacturers of **electrical and electronic products** are extremely concerned with presenting a caring, environmentally friendly corporate image and have adopted a very precautionary attitude with regards to hazardous chemicals in their products. Conscious of avoiding any bad publicity with regards to their products, OEMs such as Sony, Phillips and Dell are keen to be considered as eco-friendly companies by an ever more discerning buying public. These key companies all have their own restricted material programs which include lists of banned materials as well as policies on the phasing out of compounds which are of concern to their environmentally conscious end-consumers. As well as including substances banned by RoHS, these lists also contain chemicals **not officially outlawed by any regulatory body** [emphasis added]. One such example is the restriction on chlorinated flame retardants; although not officially banned, the carcinogenic concerns surrounding chlorinated compounds have lead many OEMs to restrict their use in their products.

The table on the next page provides information on restricted materials for four corporations involved in manufacturing electronic equipment (computers, televisions, etc.).

Restricted Materials Lists in Electrical & Electronics Equipment			
Sony	Dell	Phillips	Electrolux
Cadmium	Cadmium	Cadmium	Cadmium
Lead	Lead	Lead	Lead
Mercury	Mercury	Mercury	Mercury
Hexavalent Chromium	Hexavalent Chromium	Hexavalent Chromium	Hexavalent Chromium
Polychlorinated Biphenyls	Polychlorinated Biphenyls	Polychlorinated Biphenyls	Polychlorinated Biphenyl Ethers
Polychlorinated Naphtalenes	All Halogenated Flame Retardants in Plastics	Polychlorinated Naphtalenes	Phtalates
Chlorinated Paraffins	Short-chain Chloroparaffins	Short-chain Chloroparaffins	Short-chain Chloroparaffins
Other chlorinated organic compounds	Other chlorinated organic compounds	Other chlorinated organic compounds	Other chlorinated organic compounds
Polybrominated Biphenyls	Polybrominated Biphenyls	Polybrominated Biphenyls	Polybrominated Biphenyls
Polybrominated Diphenyl Ethers	Polybrominated Diphenyl Ethers	Polybrominated Diphenyl Ethers	Polybrominated Diphenyl Ethers
Other brominated organic compounds	Other brominated organic compounds	Polycyclic Aromatic Hydrocarbons	Halogenated Organophosphorus compounds
Organotin compounds	Nickel	Organotin compounds	Aromatic amines
Asbestos	Asbestos	Asbestos	Asbestos
Azo compounds	Azo compounds	Azo compounds	Polycyclic Aromatic Hydrocarbons
PVC + PVC blends	PVC + PVC blends	PVC + PVC blends	PVC + PVC blends

Lists such as these force suppliers of plastic additives as well as plastic processors to follow suit and offer alternatives which comply with their customers' requirements.

See Frost & Sullivan. May 18, 2005 Electrical & Electronics; pioneering the conversion to non-halogenated flame-retardants: [www.frost.com/prod/servlet/market-insight-top.pag?docid=38414884](http://www.frost.com/prod/servlet/market-insight-top.pag?docid=38414884)

### 2/3. Other Electronic Applications (cable/wire, internal electrical components, building construction) and Medical Equipment/Devices

**Affordability of DecaBDE alternatives appears to be a minimal issue** here depending of the type of electronic device or component. However, **medical equipment may have moderate affordability issues** due to the laboratory testing required before completing the Deca transition.

## Other Electronic Applications

- Cable/wiring: A review of Cable/wire industry websites indicates that companies are offering “green” and European RoHS compliant products for many applications.

- Tyco Electronics website and news dated October 6, 2005 “Tyco Electronics has continued its RoHS leadership with the availability of Madison Cable brand... These cables are designed with several national and international environmental initiatives in mind. The initiatives include Proposition 65 in the state of California, the EU RoHS and WEEE directives taking effect in 2006, and other global laws including China’s proposed hazardous substance legislation, and the Japan Green Program as well as other directives which address lead, heavy metals and other hazardous substances.” (see [www.tycoelectronics.com](http://www.tycoelectronics.com))

- Article July, 18, 2005, Green Wire-Automotive wiring gets an environmentally friendly coating, Ed Monroe, a cable program manager at Delphi, “Automotive OEMs have been asking us not just for a material that is halogen-free but also for one that is recyclable.” (see [www.designnews.com/article/CA625538.html](http://www.designnews.com/article/CA625538.html))

- New England Wire Technologies website offers RoHS compliant wire and cable that includes concentrations of PBDEs at 0.1%. They also state “We are designing and manufacturing many new RoHS compliant products each day... (see [www.newenglandwire.com/greenline.asp](http://www.newenglandwire.com/greenline.asp))

- Hitachi Cable website offers an ECO-Green line of cables that emit no toxic gases including halogen, hydrogen, chloride, and dioxins. Consumers of our cost-effective products include government agencies and local municipalities promoting the creation of “green” government offices. (see [www.hitachi-cable.co.jp/en/hc-news/357/product\\_1.html](http://www.hitachi-cable.co.jp/en/hc-news/357/product_1.html))

- In early 2001 the Toxics Use Reduction Institute (TURI) in Massachusetts began working with industry by starting a Wire and Cable Initiative that developed alternatives to PBDE brominated flame retardants. Also, the USEPA’s Design for the Environment-Wire and Cable Partnership has helped encourage production of “green”, halogen free wire/cable.

- National Semiconductor recently announced plans to “significantly” reduce bromine and antimony based flame retardants in an effort to make more “environmentally neutral” electronic components. (see [www.allbusiness.com/government/environmental-regulations/772968-1](http://www.allbusiness.com/government/environmental-regulations/772968-1))

- Amkor Technology, inc. recently announced it has been awarded “green partner” status from Sony... According to Amkor, the status was achieved, in part, as a result of the company discontinuing the use of... brominated flame retardants in plastics, molding compounds and some substrate core materials.”

- The National Electrical Manufacturers Association (NEMA) in their document titled NEMA Environmental “Call To Action”-Goals and Statement Of Principles –July 2006 Phase one: NEMA products within the scope of 2006 EU regulatory thresholds for 6 priority substances (one of which is PBDEs) will achieve or exceed those thresholds by July 1, 2010, unless it can be demonstrated that an exemption is necessary.

### **Medical Equipment**

- Our contacts with the Electronics Industries Alliance (EIA), General Electric Healthcare Division, and Underwriter’s Laboratories (UL) all confirmed that the medical industry will need additional time to complete a transition away from DecaBDE. The medical devices that may include DecaBDE require extensive laboratory testing for product safety and performance before changes to the devices can be approved.
- February, 2007 contact with Underwriter’s Laboratories (UL) confirmed that electrical safety issues in the medical equipment industry are extensive and are regulated by the International Electrotechnical Commission (IEC).
- The requirements for the electrical safety of medical equipment are much more stringent than those for other electrical devices. The reasons for increased precautions include:
  - Patients may be connected to several medical devices simultaneously,
  - Patients may be connected conductively to electronic circuitry (e.g., ECG monitoring),
  - Contact with device may be directly to internal tissues that conduct well. (see [www.601help.com](http://www.601help.com) or [www.devicelink.com](http://www.devicelink.com) for more information on medical device electrical safety issues including International Electrotechnical Commission (IEC) standard IEC60601-1 for medical devices.

<h3><b>4. Textile and Foam Industries</b></h3>
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Affordability of DecaBDE alternatives **appears to be a moderate issue** here and only as it relates to the **transportation industry**. This industry appears to already have made an orderly and timely transition away from PBDEs including DecaBDE in residential and business applications by using alternative flame retardants or different approaches to improve product flame retardant qualities e.g., use of natural, highly cleaned fabrics, flame barriers. Our review of available literature and industry participants confirmed that transition away from PBDE flame retardants (including DecaBDE) has primarily been successful in this industry. Examples of PBDE related activities in this industry include:

- Verlo Mattress Factory does business in Illinois and the Corporation and their fabric and foam suppliers confirmed that transition away from brominated flame retardants has been completed. Frequently the mattresses use a natural cotton



fabric with a boric acid treated barrier to comply with flame retardancy requirements and foam is not treated with PBDE retardants.

- Major textile/fabric suppliers like Culp Inc. stated that brominated flame retardants like DecaBDE are not used in residential type applications (e.g., furniture). However, DecaBDE is currently used in fabrics supplied to the recreational vehicle (RV) industry. (website/contact information at [www.culpinc.com](http://www.culpinc.com)).
- Ashley furniture that does business in Illinois and their suppliers of foam and fabrics confirmed elimination of brominated flame retardants. The two main suppliers of foam used in Ashley furniture stated that they had moved away from FRs containing bromine over the last couple of years. One supplier stated that they use bromine-free FRs in foam, for example phosphate based E-AB053 (made by Akzo Nobel Chemical Company). Another FR that is less frequently used in foam is Firemaster 550 (made by Chemtura) and this product is a phosphate/bromine blend (contacts available at [www.carpenter.com](http://www.carpenter.com)).
- USEPA helped establish the Furniture Flame Retardancy Partnership (as part of the USEPA's Design for the Environment Program) which is a joint venture between the Furniture Industry, Chemical Manufacturers, Environmental Groups, and the USEPA to better understand fire safety options for the furniture industry. The Partnership worked to identify and assess environmentally safer chemical alternatives to PentaBDE. However, the Partnership also looked at other technologies for improving furniture fire safety like barrier technologies, graphite impregnated foams, and surface treatments. These types of technologies could be used as alternatives to DecaBDE. The Partnership would also like to stimulate innovation by providing EPA recognition for next-generation, safer chemical flame retardants and safer non-chemical technologies. This type of group has helped the textile and foam industries to quickly transition away from brominated FRs. (See website: <http://www.epa.gov/opptintr/dfe/pubs/flameret/ffr-alt.htm>)
- Interface Fabrics: is the world's largest and most comprehensive resource for interior fabrics and fabric services. Applications of Interface Fabrics' fabrics are found in many applications including:
  - Acoustical
  - Ceilings
  - Cubicle Privacy Curtains
  - Panel/Vertical Surfaces
  - Seating
  - Window Treatment

The website address is <http://www.interfacefabricsgroup.com/home.html>

The Director of Environmental Management at Interface Fabrics indicated that in their industry, a sufficient amount of affordable PBDE alternatives have been identified for a vast majority of product needs. The key remaining variable is a

timing issue to allow the alternatives to be incorporated into products and to allow for the extensive re-testing and laboratory work to meet consumer product safety testing requirements.

The Director agreed with our assessment that the automotive and airline industries are lagging behind other industries. Previous emphasis on the PBDE issue has been concentrated initially on electronics and textile/bedding. Now, use of PBDE flame retardants in the transportation industry is being addressed. Interface Fabrics has completed several auto product trials using Deca/PBDE alternatives and trials for the airline industry are scheduled.

The Director also agreed that a key factor driving industry away from DecaBDE is public relations issues especially those surrounding the fact that PBDEs like DecaBDE are found in mother's milk.

The Director also mentioned that states like Illinois could assist companies in obtaining access to laboratories which currently are in high demand and have waiting lists for activities like the testing of DecaBDE alternatives.

- Website and article reviews indicated the following:
  - 10/11/2006 Sekisui Voltek, LLC internet article states: Sekisui Voltek, LLC a manufacturer of closed-cell polyolefin foams, has eliminated decabromodiphenyl ether di oxide (DBDE) from all flame retardant foam grades manufactured by the company
  - SpecialChem website discusses that “to address this new market need, halogen free phosphorous FR are available today” referring to FR used in polyurethane foams. (see [www.specialchem4polymers.com](http://www.specialchem4polymers.com) and search on the term halogen free.)

## 5. Transportation Industry

**Affordability of DecaBDE alternatives appears to be a significant issue here.** As mentioned earlier, roughly 80% of DecaBDE use is believed to be in electronic enclosures for televisions, computers, medical equipment etc. While the transportation industry does not use DecaBDE at the high concentrations/levels found in electronic enclosures, DecaBDE is more distributed throughout the airliners/vehicles. Also, DecaBDE is found in a wider variety of components including wiring, fabrics, and fuel systems. Some of the proposed house bills in other states provide exemptions for the transportation industry. For example, Washington legislation potentially limiting DecaBDE exempts transportation vehicles and parts and allows the environmental agency to grant exemptions for the use of PBDEs under certain circumstances.

### Airline

Affordability issues appear to be a **very significant issue here.** Boeing representatives, for example, stated that some airliners have over 1 million component parts. While Boeing has been successful in removing many of the brominated fire retardants, DecaBDE is contained in many component parts from interior plastics, interior fabrics, and other electronic parts/wiring. It can take 5-7 years to get FAA approval on modifications to an airliner including the changing of FRs. Boeing confirmed that Illinois has suppliers of parts that may have DecaBDE, however, they were unable to confirm how many Illinois companies supply parts to Boeing.

### Automotive/Recreational Vehicle

- The engineering staff at Illinois based Mitsubishi Motors in Normal Illinois provided the following in regards to a potential requirement to use DecaBDE alternatives: "...it does appear that this will have little impact on cost for Mitsubishi, as our suppliers were made aware of this potential legislation (banning of p-BDE and o-BDE in some states) roughly one year ago, and have accordingly engineered these compounds (including d-BDE) out of their product."
- In an article supplied by the Alliance of Automobile Manufacturers (trade group of 9 auto manufacturers) titled Deca Brominated Diphenyl Ether Automotive Usage states that:
  - Major automotive systems containing Deca are: electrical wiring, electronics and fuel systems,
  - Because there are hundreds of component suppliers and thousands of components per vehicle, the number of components containing Deca is not known,
  - In a typical vehicle, there are dozens of electrical wiring and electronic components alone which contain this flame retardant (referring to Deca),
  - Elimination of Deca from automobiles is expected to take approximately 5 years to accomplish,
  - Service parts should be exempted such as was adopted in many Penta and Octa bans. Service parts are generally built years in advance.

- Discussions with one of the largest producers of fabric in the United States indicated that DecaBDE is not used in residential furniture products. However, DecaBDE is still used extensively in fabrics found in recreational vehicles.
- Slow but sure movement away from halogen chemicals is occurring: The article Green Wire Automotive wiring gets an environmentally friendly coating states: “Automotive OEMs have been asking us not just for a material that is halogen-free but also for one that is recyclable. Delphi Corporation and GE Advanced Materials developed a new wire coating that lacks the halogens and potential for dioxin release.
- Environmental Director at Interface Fabrics stated that the transportation industry needs more time for testing and laboratory work and year-end 2010 appears to be a reasonable timeline here.
- Information recently published by Ecology Center (see [www.ecocenter.org](http://www.ecocenter.org)) highlighted the extremely wide variance as far as some automobile manufactures have already transition away from brominated flame retardants like DecaBDE however, some automobiles still have brominated flame retardants. The Ecology Center data did not however always specify the types of brominated FRs found. The potential for a wide variance in the transition from DecaBDE in the automotive industry, requires that **Illinois work closely with transportation industry manufactures to monitor and complete the transition.**

## **REFERENCES FOR APPENDIX IV: OVERVIEW AND DISCUSSION OF AFFORDABILITY AND AVAILABILITY ISSUES**

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