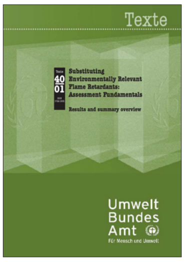
Studies on Alternatives to Brominated and Chlorinated Substances

Passages with relevant information regarding alternatives to BFRs in the listed studies have been extracted and highlighted here. Note that these are not a summary of the study. For complete studies, please see links to websites.

GOVERNMENTAL STUDIES

German UBA (Federal Environmental Agency)



Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals Volume 1: Results and summary overview, 2001.

http://www.umweltdaten.de/publikationen/fpdf-l/1988.pdf

Less know-how is generally available with regard to the presented alternatives than for the traditionally brominated flame-retarded printed circuit boards. The available information however shows that the substitution of brominated flame protection in printed circuit boards is both possible and sensible. This is supported by the available information about the substitutes and the by-products of fire that they produce.

Insofar as comparative examinations of products (printed circuit boards) have been presented, the halogen-free flame-retarded printed circuit boards fare distinctly better with regard to the by-products of fire. Insofar as the alternative flame-protection systems consist of reactively bound phosphoric and nitrogen compound flame retardants, it is to be expected that they, like brominated flame-retarded printed circuit boards, do not exhibit any relevant gas emission or migratory behaviour under normal operating conditions, but only in the event of fire. In contrast, the expected gas emission and migration behaviour must be critically examined in alternatives that are based on additive flame retardants. Abandoning the use of halogenated flame retardants could make the recovery of material (copper) as well as an intended particle recycling easier, despite the basic obstacles to recycling duroplastic printed circuit boards.

United Nations Environment Programme

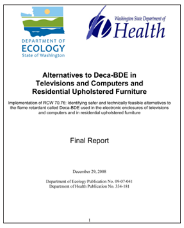
Guidance on alternative flame retardants to the use of commercial pentabromodiphenylether (c-PentaBDE), Stockholm Convention on Persistent Organic Pollutants, 2009

http://chm.pops.int/Portals/0/Repository/poprc4/UNEP-POPS-POPRC.4-INF-13.English.DOC <http://chm.pops.int/Portals/0/Repository/poprc4/UNEP-POPS-POPRC.4-INF-13.English.DOC>

The objective of this report has been to review possible alternatives to PentaBDE. The available data illustrate that there are alternative flame retardants commercially available which are less hazardous than C-PentaBDE. It should be the overall target to replace harmful substances with safer options, but it is also important to point out that the alternative flame retardants presented need to be evaluated based on their range of application.

Although the use of brominated flame retardants is still growing by around 5% per year, their use is strongly questioned due to their potentially harmful environmental and health characteristics. A number of brominated flame retardants are already restricted in several countries worldwide. Due to further restrictions and public concern against health and environmentally hazardous chemicals, brominated flame retardants have no future.

Washington State Department of Health


DEPARTMENT OF ECOLOGY
State of Washington
Health
Alternatives to Deca-BDE in Televisions and Computers and Residential Upholstered Furniture
Final Report

Alternatives to Deca-BDE in Televisions and Computers and Residential Upholstered Furniture. Department of Ecology State Washington, 2008.
www.ecy.wa.gov/biblio/0907041.html

In evaluating alternatives to the use of Deca-BDE in electronic enclosures, Ecology and DOH focused on non-halogenated flame retardants which are less likely to persist in the environment and to bioaccumulate in organisms. Non-halogenated alternatives also have the added benefit of being much more easily degraded than their halogen equivalents, thereby reducing their potential long-term impact on human health and the environment.

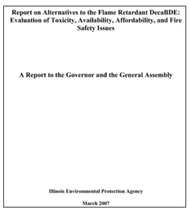
After reviewing recent studies, reports and other information, most of which became available after the PBDE Chemical Action Plan was completed, Ecology and DOH identified two possible phosphate-based flame retardants: resorcinol bis diphenyl phosphate (RDP) and triphenyl phosphate (TPP), as technically feasible alternatives.

The agencies then conducted a review of information available on these two flame retardants to determine if both could be recommended as safer alternatives to Deca-BDE. This review included a comparison of toxic effects levels observed in animal studies and an evaluation of aquatic toxicity information. Based upon this evaluation, the agencies found that RDP is a safer and technically feasible alternative to Deca-BDE. TPP was eliminated due to concerns related to its aquatic toxicity.

The agencies then conducted a review of information available on these two flame retardants to determine if both could be recommended as safer alternatives to Deca-BDE. The Fire Safety Committee unanimously found that RDP meets applicable fire safety standards.

Conclusions: Safer, technically feasible alternatives to the use of Deca-BDE in TVs, computers and residential upholstered furniture are available and meet applicable fire safety standards.

Illinois Environmental Protection Agency

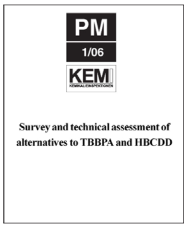

Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues
A Report to the Governor and the General Assembly
Illinois Environmental Protection Agency
March 2007

Report on Alternatives to the Flame Retardant DecaBDE : Evaluation of Toxicity, Availability, Affordability and Fire Safety Issues, March 2007.
http://www.epa.state.il.us/reports/decabde-study/decabde-alternatives.pdf

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.

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.

The Swedish Chemicals Inspectorate



Survey and technical assessment of alternatives to TBBPA and HBCDD, PM 1/06, 2006.

http://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_06.pdf

Phosphorus containing flame-retardants mainly influence the reactions during fire that take place in the condensed phase. They are particularly effective in materials with high oxygen content, such as oxygen containing plastics as well as cellulose and its derivates. The range of phosphorous containing flame-retardants is extraordinary versatile since, in contrast to halogen compounds, it extends over several oxidation states.

Inorganic flame-retardants are suitable for use in plastics since these compounds are too inert to be effective in the decomposition of plastics in the temperature region of 150`C to 400`C, where most plastic materials decompose. Apart from antimony trioxide, which is a synergene to halogen flame-retardants, the most widely used inorganic flame-retardants are aluminium hydroxide and boron containing compounds that affect the combustion process of plastics by physical means. Unlike organic flame retardants, inorganic flame retardants do not evaporate under the influence of heat, but they emit non-flammable gases such as water or carbon dioxide, which dilute the mixture of flammable pyrolysis gases and forms a protective layer on the surface against further oxygen attack and against further propagation of the fire.

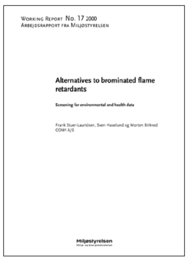
The Swedish Chemicals Inspectorate

Survey and technical assessment of alternatives to Decabromodiphenyl ether (decaBDE) in plastics, 1/05, 2005

http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport1_05.pdf

TBBPA is mainly used in epoxy resins on the market as a reactive flame retardant. There are a number of reactive nitrogen and phosphorous compounds and additive inorganic alternatives, mainly aluminium trihydrate that are used on a commercial basis as alternative non-halogen flame retardants in epoxy resins instead of TBBPA.

Danish Environmental Protection Agency



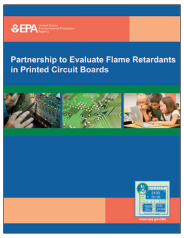
Environment Project no.1141, 2006, *Deca-BDE and Alternatives in Electrical and Electronic Equipment*.

http://www2.mst.dk/Udgiv/publications/2007/978-87-7052-349-3/pdf/978-87-7052-350-9.pdf

The Danish Environmental Protection Agency has initiated several projects on flame retardants. The present project is a screening of the reviews, hand- books and readily available literature and databases for information on environmental and health properties for a number of alternatives to brominated flame retardants.

The type of data that are missing varies between compound. Typically missing data on the environment side are biodegradation data and bioaccumulation data. On the health side a less clear pattern is observed.

US Environmental Protection Agency



Partnership to Evaluate Flame Retardants in Printed Circuit Boards, 2008.

http://www.epa.gov/dfeprojects/pcb/full_report_pcb_flame_retardants_report_draft_11_10_08_to_e.pdf

This document contains the first part of a two-part report addressing environmental and human health issues associated with the production, use, and disposal of FR4 PCBs using current and emerging flame retardant technologies. Part one provides an evaluation of the environmental and human health hazards associated with flame retarding chemicals during manufacturing and use of the FR4 boards and a preliminary discussion and identification of end of life issues. Part two of the report will present experimental data from the investigation of the thermal breakdown of boards and the byproducts formed under different combustion and pyrolysis conditions. These data may provide further insight into any issues that may arise, including possible end of life disposal issues. It is anticipated that part two of the report will be completed in 2010.

There has been a continuous increase in the demand for halogen-free material over the past few years. In 2003, the global halogen-free laminate market was approximately $60 million. In 2004 this market grew to $161 million, in 2005 it reached $239 million, and it is estimated at $307 million for 2006. Most laminate suppliers now include halogen-free materials in their portfolio.

In the absence of proper control equipment, the smelting process may pose risks to workers and the public through exposure to toxic chemicals. Halogenated flame retardants, for example, can lead to the formation of dioxins during the smelting process if proper safety measures are not installed (Umicore, 2006).

Danish Environmental Protection Agency

Working report nr. 17, 2000., *Alternatives to brominated flame retardants. Screening for environmental and health data.*

http://www2.mst.dk/Udgiv/publications/2000/87-7944-218-8/pdf/87-7944-219-6.pdf

This study has not identified any application of Deca-BDE in electrical and electronic equipment for which substitution is not possible, from the scientific or technical point of view. For all EEE materials and components presently using Deca-BDE, technically acceptable alternatives are available on the market. The widespread use of alternatives, and availability of EEE components without Deca-BDE, is indicated by the fact that a large number of the world's major manufacturers of EEE have phased out the use of Deca-BDE in their products.

Today a significant percentage of CRT-TV housings sold on the European market are still made from HIPS (plastic material) without FR, but the major European manufacturers of TV-sets now seem to be using copolymers like PC/ABS, PS/PPE or PPE/HIPS either without FRs, or with non-halogenated FRs

Based on a description of the product chain of equipment containing Deca- BDE, the impact of a Deca-BDE ban on the different industrial sectors is briefly discussed. The impact is highly dependent on whether Deca-BDE is replaced with other brominated flame retardants with nearly the same properties as Deca-BDE, or whether it is replaced with halogen-free flame retardants, sometimes including changes of the resin as well. In the first case the impact is mainly implying the use of more expensive flame retardants. Any shift to halogen-free alternatives in EEE is, on the other hand, not driven by the introduction of a ban on Deca-BDE, but should rather be seen as part of a more general ongoing movement toward the use of halogen-free flame retar- dants driven by consumer demand, eco-labels, NGO actions, etc.

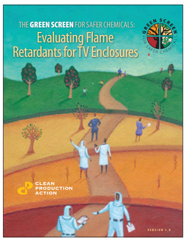
NON GOVERNMENTAL STUDIES

Pinfa (Phosphorus, Inorganic and Nitrogen Flame Retardants Association)

Fact sheets on hazard profiles of non halogenated flame retardants
www.halogenfree-flameretardants.com
Brochure download: http://www.halogenfree-flameretardants.com/HFFR-300.pdf

The brochure illustrate the technical properties and advantages of halogen-free flame retardants (FRs) for key application areas like housings, cables, connectors and switches as well as printed wiring boards. After many years of research and development a whole toolbox of halogen- free chemistries is now available for the materials engineer. In some areas, the development of commercial solutions is moving quickly.

Clean Production Action



The Green Screen for Safer Chemicals: Evaluating Flame Retardants for TV Enclosures, March 2007.
http://www.cleanproduction.org/library/Green_Screen_Report.pdf

The Green Screen for Safer Chemicals defines a path to chemicals that are safer for humans and the environment. It is a rigorous, hazard-based screening method that is designed to inform decision making by businesses, governments, and individuals concerned with the risks posed by chemicals and to advance the development of green chemistry. The Green Screen defines four benchmarks on the path to safer chemicals, with each benchmark defining a progressively safer chemical:

- Benchmark 1: Avoid—chemical of high concern
- Benchmark 2: Use but search for safer substitutes
- Benchmark 3: Use but still opportunity for improvement
- Benchmark 4: Prefer—Safer chemical

The Green Screen assessed three flame retardants that currently meet performance criteria for use in the external plastic housing of televisions (TVs): decaBDe and two phos-phorous-based alternatives, resorcinol bis (diphenylphosphate) (RDP), and bisphenol a diphosphate (BaPP or BPaDP). Of the three flame retardants, RDP was the only flame retardant to pass all criteria under Benchmark 1 of the Green Screen. An integral element of the Green Screen is taking into account potential degradation products and metabolites. Both decaBDe and BPaDP scored lower on the Green Screen because of their degradation products. While RDP is not a "green chemical" per se, based on assessment via the Green Screen for Safer chemi- products), is a safer chemical.