An Update of the Regulatory, Environment, and Performance Status of Tetrabromobisphenol-A in Printed Wiring Boards

Brian Carter and Susan D. Landry
Albemarle Corporation

Abstract
Tetrabromobisphenol-A (TBBPA) is a commercial flame retardant used in rigid FR-4 printed wiring boards (PWB). It is the single largest volume brominated flame retardant in the world. In this application, the TBBPA is fully reacted into the epoxy resins that form the base material of the PWB. TBBPA's leadership position in the rigid printed wiring board market is due to several factors, including reliable performance over time.

This paper will look at the benefits of TBBPA as a flame retardant in epoxy resin PWB. It will also address the current regulatory status of TBBPA and PWB recycle. An update on the status of the EU Risk Assessment on TBBPA and other industry assessments that compare TBBPA to alternative flame retardants for PWB will be included.

Introduction
Printed wiring boards (PWB), also called printed circuit boards, evolved from electrical connection systems (metal rods mounted on wooden bases) that were developed in the 1850s [1]. In 1925, Charles Ducas of the US submitted a patent application for a method of creating an electrical path directly on an insulated surface by printing through a stencil with electrically conductive inks. This method was used to coin the name "printed wiring" or "printed circuit."

In 1943, Paul Eisler of the United Kingdom patented a method of etching the conductive pattern, or circuits, on a layer of copper foil bonded to a glass-reinforced, non-conductive base [1]. Widespread use of Eisler's technique did not come until the 1950s when the transistor was introduced for commercial use. With the advent of transistors, however, the components became very small, and manufacturers turned to printed circuit boards to reduce the overall size of the electronic package. Integrated circuit chips were introduced in the 1970s, and these components were quickly incorporated into printed circuit board design and manufacturing techniques [1].

PWB hold microchips and other electronic components used to run computers, telecommunications equipment, industrial controls and other devices. Because the very function of circuit boards is to transmit electrical charges, flame retardants are an absolute necessity. Exposed to constant heat and electrical current, PWB base laminates can be made of either epoxy or phenolic (thermoset) resins, rigid or flexible that are required to meet certain flammability standards. (FR-4 boards, for example, must meet UL94 V-1 ratings). Currently, over 90 percent of the PWB produced meet the UL 94 V-0 standard for fire safety [2].

Fire Safety
The need for flame retardancy has long been recognized. Throughout history, the Egyptians and Romans used alum or mixtures of alum and vinegar to reduce the combustibility of wood [3, 4]. Today, despite our best efforts, fire continues to be a major problem in our society. It is estimated that there were about 166,000 fire deaths worldwide in 2001 at a cost of about 400 € billion [5]. In the US in 2005, fires killed more than 3,700 people, injured more than 17,000 people, and resulted in property damages estimated at $10.7 billion [6].

The use of plastics in many different applications (such as appliances, TVs, automobiles, computers, cell phones, etc.) has contributed enormously to economic manufacture and use of these items though out our society. Plastics provide a balance of performance characteristics that no other class of materials can match. The majority of the plastics that are used are petroleum-based and hence are flammable. For reasons of fire safety, the need to incorporate flame retardants into polymer formulations has grown. Flame retardants are used to delay the spread of fires or delay the time of flashover to enable people time to escape. They play a significant role in making homes, hotels, hospitals, nursing homes, offices, automobiles, and public transportation safer. It is estimated that escape times can be up to 15 times longer when flame retardants are present, providing increased chances of survival [7]. The proliferation of electronic equipment over the past two decades has resulted in an increased demand for PWB. Since the PWB base laminates are exposed to constant heat and electrical current, flame retardants must be incorporated to insure proper fire safety.

To improve the flammability of epoxy-based PWB, tetrabromobisphenol-A (TBBPA) has been the flame retardant of choice for around 30 years. Alternative flame retardant materials are used in only 3-5% of FR-4 boards. TBBPA is reactive and is incorporated into the backbone of the epoxy resin and, therefore, will not leach out of the polymer. At this point, TBBPA no longer exists in the final PWB as TBBPA, it is part of the epoxy polymer. SAYTEX® CP-2000 Flame Retardant is TBBPA produced by Albemarle Corporation [8]. It has stable aromatic bromine, high purity, low ionic content, and polymers based on this product possess excellent electrical properties.

Flame Retardant Regulatory Activity

Flame retardants, as well as other materials, are coming under scrutiny due to perceived environmental and toxicological issues. Concerns with the detection of low levels of various chemicals in the environment and human tissues have led to the assessment of potential environmental or human health effects of numerous high production volume chemicals. A great deal of information is increasingly available on the potential health and environmental effects of those commonly used flame retardants that have or are undergoing risk assessment.

EU Risk Assessment

The EU Risk Assessment program is one process that has been in place for over ten years that is used to evaluate the characteristics of a variety of high production volume chemicals. It is the most comprehensive of current global assessment programs for human health and environmental characteristics. Several flame retardants have completed or are currently undergoing EU Risk Assessments. Each flame retardant is being assessed individually, not as a class. This process examines critical aspects of a chemical, including mammalian and environmental toxicology, environmental fate and releases (to water, soil, air, and from all operations throughout the lifecycle), and risk (exposures versus limits). After all this information is generated, a hazard assessment, exposure assessment, risk identification, and risk management is generated. This will determine whether there is a need for more testing or whether there is a need for risk reduction. The risk assessment is the basis for the future legislation on the use of these substances in the European Union. Figure 1 contains the expected timeline for the EU Risk Assessment on TBBPA.

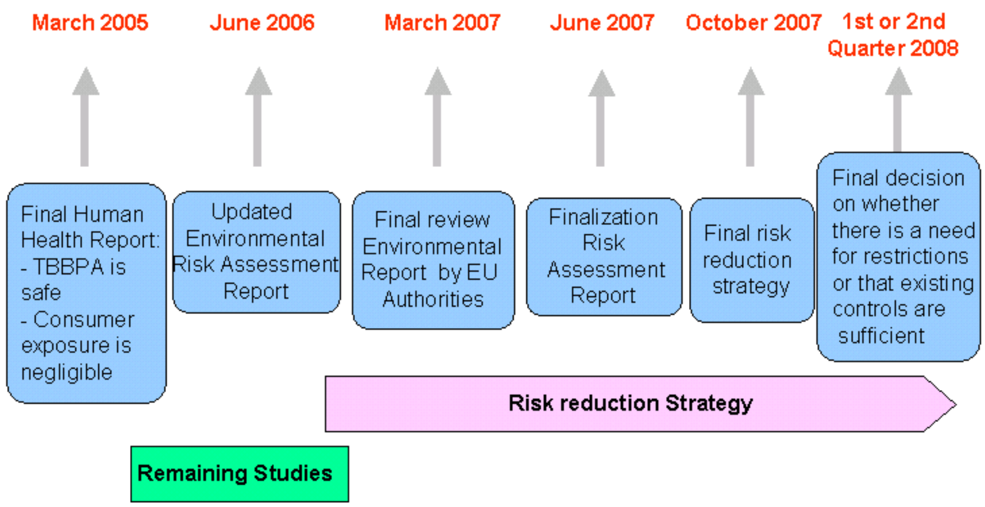


Figure 1 – TBBPA EU Risk Assessment Expected Timeline

The human health section of the EU Risk Assessment concluded that TBBPA has no risks and there is no need for risk reduction measures in any of the scenarios [9]. The European Authorities also agreed that TBBPA does not need to be classified for human health. It is not a PBT (persistent, bioaccumulative, and toxic) material. The EU Scientific Committee on Health & Environmental Risks (SCHER) confirmed the EU Risk Assessment conclusions that TBBPA presents no human health risk [10]. This scientific expert panel reporting to the EU Commission is always consulted after the finalization of EU risk assessments. A study from the University of Würzburg performed under the EU FIRE project also confirmed the conclusions of the EU human health Risk Assessment report which identified no risk to human health from the use of TBBPA [11].

The environmental section of the EU Risk Assessment on TBBPA is still in progress, and completion is expected in March or June of 2007.

The current Risk Assessment for reactive use of TBBPA indicates no risk reduction measures are foreseen, providing that sewage sludge is not spread on agricultural soil. The reason for this positive profile is the negligible exposure potential due to the fact that in its primary application, TBBPA is completely reacted into the final polymeric resin. As such, TBBPA does not exist in the final FR-4 board.

The EU-funded cluster of research projects into endocrine disrupting chemicals (CREDO) found "no cause for concern" for TBBPA. Within the CREDO cluster, the FIRE Project (Flame retardants Integrated Risk assessment for Endocrine effects) studied 3-month exposure to TBBPA of estuarine flounders (flat fish). Despite the significantly higher exposure levels than those found in the natural environment, the CREDO report concludes that for TBBPA "general health and toxicity parameters (behavior, survival, growth rate, and relative liver and gonad weight) were not affected" [12].

EU REACH

The new proposed EU chemical legislation "REACH" is now moving towards adoption, with the final details in the process of being determined. REACH is the acronym for **R**egistration, **E**valuation and **A**uthorization of **CH**emicals. The REACH proposal will affect all of the chemical industry, including flame retardants, by requiring industry to register all existing and future new substances with a new European Chemicals Agency. REACH is expected to be finalized in early 2007 and enter into force by mid 2007. From then, the 18-month period for Pre-Registration of substances will open. TBBPA should be one of the first substances registered under the REACH. This is due to special provisions for substances that have already undergone the EU Risk Assessment under Regulation 793/93/EC.

EU RoHS Directive

The Directive of the European Parliament and of the Council 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) was put into effect on July 1, 2006. It states that Member States shall ensure that new electrical and electronic equipment (EEE) put on the market shall not contain Pb, Hg, Cd, Cr (VI), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs). Decabromodiphenyl ether was exempted from the provisions of the RoHS Directive on October 15, 2005. All other flame retardants, including TBBPA, are compliant with the provisions of the RoHS Directive and can hence be used in EEE.

EU WEEE Directive

The recycling of electronic waste foreseen in the EU Directive 2002/96/EC on the Waste of Electrical and Electronic Equipment (WEEE Directive) is based on the experience of a few European Countries, where organizations managing voluntary take back systems on behalf of the EEE producers have been responsible for the collection and recycling of the WEEE. This directive calls for selective treatment of plastics containing brominated flame retardants, as stated in Annex II [13]. Also required within the directive is the separation of PWB of mobile phones (regardless of PWB size) and of other devices if the surface of the PWB is greater than 10 cm^2, regardless of what flame retardant is contained. The reason is to recover the valuable extractable metals (Ag, Au, Cu, Zn, Al, Ni) from the PWB.

The selective treatments of flame retardant plastics are fulfilled when the WEEE plastics are treated (recovered, recycled, thermally disposed) together with other wastes, as is the case with energy recovery processes that are currently practiced in Europe [14]. In this scenario, the joint recovery of plastics containing brominated flame retardants with other materials complies with the purpose of the WEEE Directive without the removal requirement of Annex II. Recent technical studies and legal reviews demonstrate that WEEE plastics containing brominated flame retardants, including TBBPA, are compatible with the EU WEEE Directive without separation and removal prior to the waste treatment. This has been confirmed by the 2006 EU Member States' guidance on the separation requirements of the WEEE Directive.

Recycle

For PWB, the main end-of-life outlet is to smelters. Copper smelters, as well as precious metal smelters, are able to use PWB as a source for energy recovery (replacing cokes) and as a reducing agent for the metals. By smelting, the copper and precious metals can be recovered in the most economical and environmental safe manner. To produce copper from recycled material rather than from ore, means that only one-sixth of the energy is needed [14].

Smelting can safely be practiced using proper conditions. Research and many years of operation have conclusively shown this to be the case. Pyrolitic treatment (typical method for smelting) involves the ignition and melting of ground feedstock in a furnace at ~1200°C via air injection. The organic constituents are destroyed at these high temperatures and emissions are addressed via afterburners [15].

It is estimated that out of a 50-75% recycling target, 55% can be achieved through the metal (smelting) recovery process. An eco-efficiency study carried out by PlasticsEurope in Belgium showed that a metal smelter provided the highest recovery rate for handling mobile phones, without high dismantling costs [14]

As an example of this process, the Swedish company, Boliden, has developed a metals recycling process for WEEE that is in compliance with European regulation. The plastics provide energy for the smelting process. A trial was recently carried out at a precious metal smelter in Antwerp to assess the feasibility of using mixed waste WEEE plastics to replace coke as a reducing agent and energy source for the smelter [16]. Approximately 150 tonnes of E-waste was fed into the smelter. A comparison was made of the operation with zero plastics input (treating wastes other than PWB and 4.5% coke) to 6% E-Waste plastics and 1% coke. Results available to date show similar smelter operation and performance (metal recovery rates, operating stability) between the two input schemes. This trial suggests that the Umicore Hoboken integrated smelter alone offers >15,000 tonnes/year capacity to treat WEEE plastics plus >40,000 tonnes/year capacity for PWB (which include around 25% plastic). Moreover, the Flemish Waste Administration granted Umicore a permit for handling WEEE plastics and agreed that this should be part of recycle quota in the WEEE directive

VECAP
A Voluntary Emissions Control Action Plan (VECAP) was initiated in the UK in 2005 for decabromodiphenyl ether (Deca-BDE). It has also been implemented in other European Member States and is currently being implemented in North America to reduce release potential of this flame retardants to the environment. Figure 2 is a diagram of the six steps of the VECAP process.

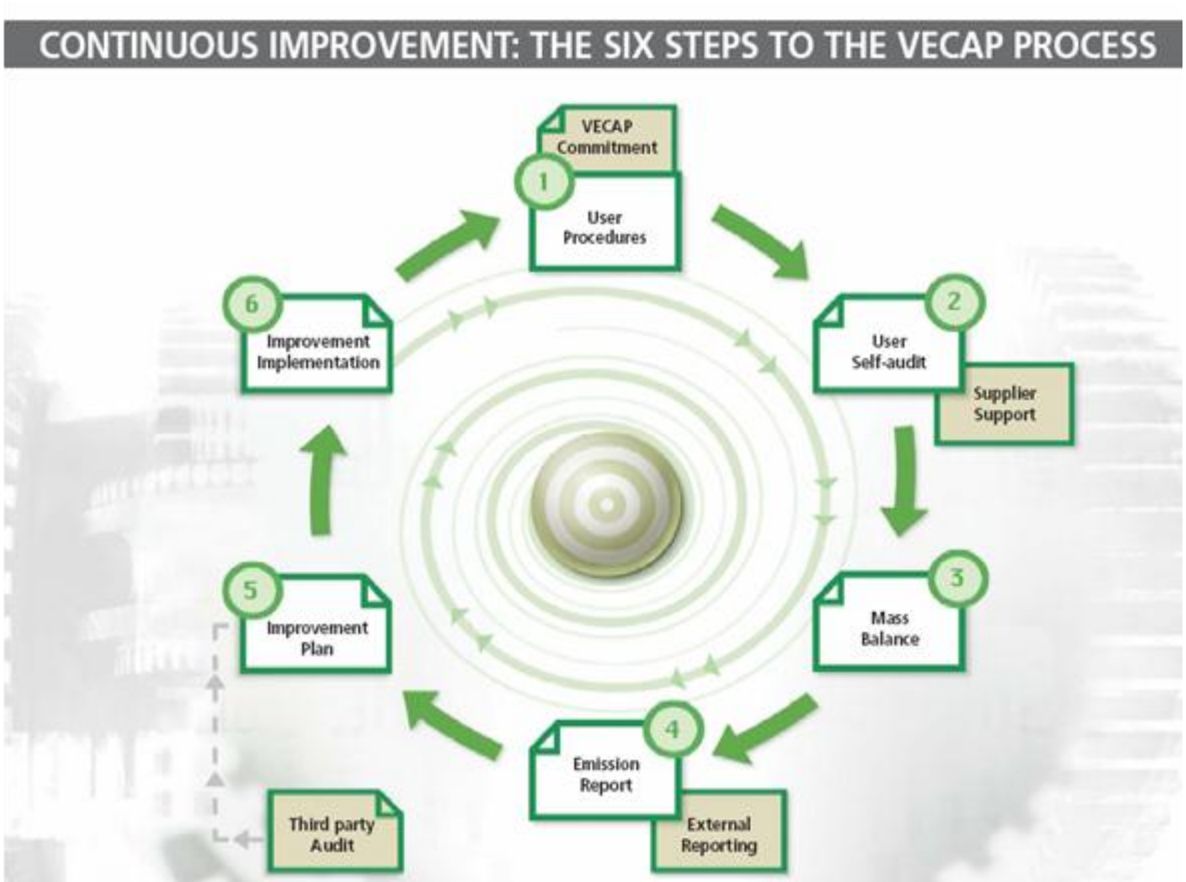


Figure 2 – VECAP Process

All industrial users of Deca-BDE in the UK textiles industries have implemented reduced emissions techniques in line with the Code of Good Practice. This initiative was started by an industry consortium to minimize emissions of the flame retardant Deca-BDE, and is already being applied in the UK textile industry to other flame retardants, such as HBCD and antimony trioxide. After one year of implementation, the UK Pilot Program achieved a 75% reduction in emissions to water by textile industries. The program was launched in five other EU Member States and is on target to cover 90% of Deca-BDE usage in the EU by June 2007 [17]. Other flame retardants, including TBBPA will also utilize the VECAP process to insure that emissions to the environment are minimized or eliminated.

Flame Retardant Options for PWB
To investigate the environmental, health, safety, and performance aspects of flame retardants that are or could be used in PWB, the electronics industry is engaging in several different projects. One project that will focus on the environmental, health, and safety aspects of flame retardants used in PWB is a multi-stakeholder partnership with EPA's Design for the Environment (DfE) Program [18]. The goal of the project is to identify and evaluate commercially available flame retardants and their environmental and human health and safety aspects in FR-4 boards. The DfE project will try to determine the potential hazards associated with various flame retardants and potential exposures throughout the life cycle of flame

retardants used in electronic FR-4 PWB. Consideration of exposures from manufacturing, use, and incineration or burning at the end of life will be included. In addition, understanding the combustion products that could be formed during certain end of life scenarios will also be evaluated.

Another project (iNEMI Halogen-Free Initiative) that will look into mechanical performance and reliability of PWB containing different flame retardants is being conducted by International Electronics Manufacturing Initiative (iNEMI). The objective of this project is to “promote standards development by establishing materials, manufacturing, assembly, and test guidelines for "halogen-free" printed wiring boards based on market segment requirements and technical, commercial, and functional viability [19].” In Phase I of this project (Design), the group will identify market segment requirements, candidate materials, key performance characteristics and test criteria. In this phase, the test vehicle(s) and test methodologies will also be designed. Phase II (Test) will consist of developing an evaluation schedule, procuring parts and test vehicles, assigning teams to perform testing, and actual mechanical and reliability testing on test vehicles. Phase III (Results) will include compiling the results, assessing the significance, making recommendations, and publishing a report. This phase will include assessing technology readiness, identifying gaps, assessing manufacturing capabilities and supply capacity.

The projects initiated by the High Density Packaging User Group (HDPUG) are the “Halogen-free PWB Properties” and “Halogen-free Component Properties” projects [20]. The projects will assemble Halogen-free guidelines and product databases (either PWB or Components). The items will be addressed from a user and supplier points of view. Some of these items could include electrical performance, mechanical integrity, ability of machining (drilling and cutting), flame retardancy, cost compared with FR-4 PWB or components containing TBBPA or existing technologies, reliability, market requirements, environmental compliance, readiness of the supply chain, today's legislation, expected future more stringent legislation, and requirements on future products.

Conclusions

The proliferation and extensive use of electrical and electronic equipment (EEE) has helped to improve our quality of life. Printed wiring boards are an integral part of this equipment. Tetrabromobisphenol-A (TBBPA) is a valuable flame retardant that has been used extensively in rigid FR-4 printed wiring boards (PWB) for over 30 years to insure fire safety and has a long history of reliable use in this application. There are no prohibitions on the use of TBBPA. It has undergone extensive human health and environmental testing, in which other flame retardants used in this application have not.

TBBPA is currently undergoing the EU Risk Assessment process. The human health section of the EU Risk Assessment has been finalized and indicates that there is no risk associated with the use of TBBPA. The environmental section of the EU Risk Assessment will not be finalized until the end of 2006 or early in 2007. Several programs have been initiated to investigate the environmental, health, safety, and performance aspects of flame retardants that are or could be used in PWB. TBBPA will be included in these programs.

Excellent product stewardship under the Voluntary Emissions Control Action Plan (VECAP) program will help to insure that TBBPA is kept out of the environment. PWB containing TBBPA have an efficient and economical end-of-life option that is already in place. At end-of-life, PWB can be treated by smelting to remove copper and precious metals that are present. The laminate (epoxy resin with TBBPA reacted into the backbone) in the PWB is a source for energy recovery (replacing cokes) and a reducing agent for the metals. The Flemish Waste Administration recently approved the treatment of PWB in a metal smelter as part of the recycle quota in the WEEE Directive.

References

[1.] http://www.madehow.com/Volume-2/Printed-Circuit-Board.html
[2.] http://www.epa.gov/dfe/pubs/projects/pcb/index.htm
[3.] www.toadspad.net/toad-history.html
[4.] www.worldbook.com/wc/features/fires/html/prevent.html
[5.] Recent Fire Statistics and Trends, Aug 2002, www.cefic-efra.org
[6.] M.J. Karter, Jr, Fire Loss in the United States During 2005, www.usfa.fema.gov
[7.] “Fire-hazard comparison of fire retarded and non fire retarded products,” NIST 1988, http://fire.nist.gov/bfrlpubs/fire88/art003.html
[8.] www.albemarle.com
[9.] http://ecb.jrc.it/esis/esis.php?PGM=ora
[10.] http://europa.eu.int/comm/health/ph_risk/committees/04_scher/docx/scher_o_020.pdf
[11.] http://toxsci.oxfordjournals.org/cgi/content/abstract/91/1/49
[12.] http://www.credocluster.info/docs/newsletter/credonews5.pdf.
[13.] Directive 2002/96/EC, Annex II of the Directive deals with selective treatment for materials and components of WEEE and lists the substances and components to be removed from WEEE.

[14.] http://www.bsef.com/recycling/thermal_processes/index.php
[15.] www.rohmhaas.com/electronicmaterials/CBT/vol2/papers/RecyclingTechnologies.pdf
[16.] Johan Brusselaers, Umicore Smelter Trial With WEEE Plastics Workshop "Where are WEEE going?," Antwerp (6-7 October 2004)
[17.] "1st Annual Progress Report of Flame Retardant Voluntary Emissions Control Action Programme," June 6, 2006, www.ebfrip.org
[18.] http://www.epa.gov/dfe/pubs/pwb/factsheet/pwbproj.htm
[19.] http://www.inemi.org/cms/projects/ese/halogen_free.html
[20.] www.hdpug.org

An Update of the Regulatory, Environmental, and Performance Status of TBBPA in Printed Wiring Boards

Susan D. Landry and Brian Carter

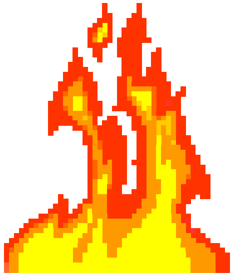
February 20, 2007

susan_landry@albemarle.com
(225) 388-7565

ALBEMARLE™

The Need For Flame Retardancy…..

…has been recognized throughout history



- Around 450 BC, the Egyptians used alum to reduce the flammability of wood
- Romans also used a mixture of alum and vinegar to reduce the combustibility of wood around 200 BC

2005 US Fire Safety Statistics

- Fire departments responded to 1,602,000 fires
- Firefighters killed – 87
- Civilians killed – 3,675
- Civilians injured – 17,925
- Direct property loss – $10.7 billion
- Structural fires –
  511,000 & 3,030 deaths
  - 82% occurred in residential properties

Source: *Fire Loss in the United States During 2005*, by Michael J. Karter, Jr.

Why use Flame Retardants?

www.albemarle.com

- Flame retardants in plastics improve fire safety
  - Lives are saved
  - Injuries are reduced
  - Economic loss reduced
  - Reduction of immediate local pollution as a result of fire

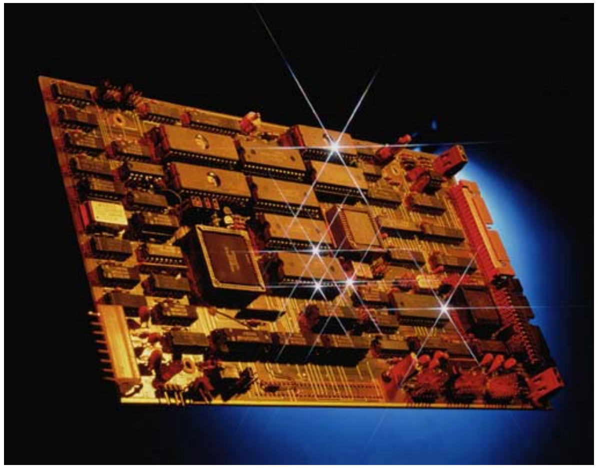
Recent Air France Crash
309 Lives Saved

***The Washington Post:* "Fire retardant material now required in aircraft cabins may have helped slow the spread of flames and smoke, enabling all crew members and passengers to escape."**

ALBEMARLE™

Why use Flame Retardants in Printed Wiring Boards (PWB)?

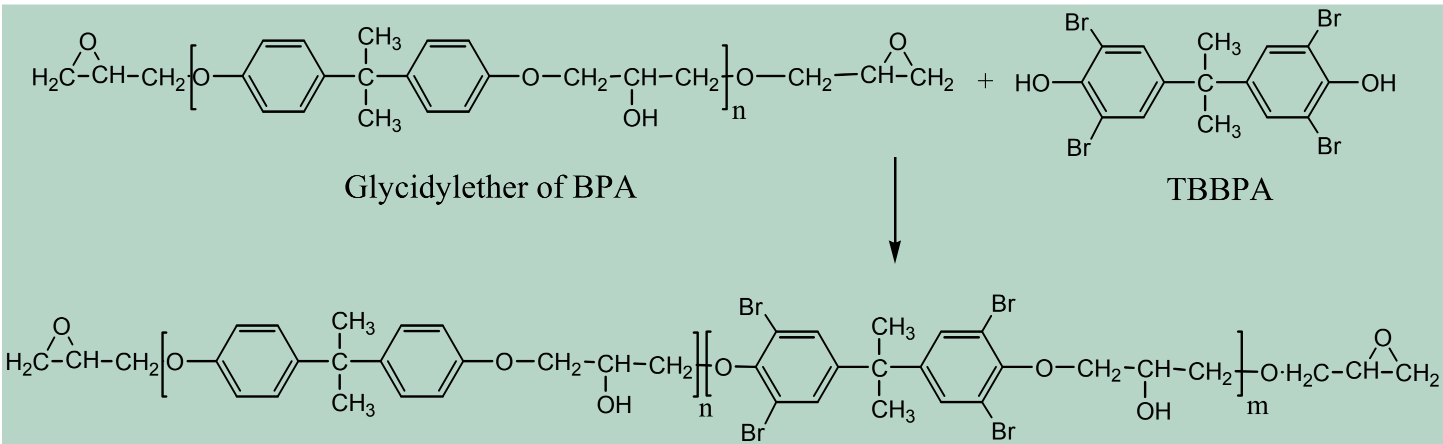
- The very function of a PWB is to transmit electrical charges
- They are exposed to constant heat and electrical current
- PWB must meet flammability standards (FR-4 boards must be UL-94 V-1 rated)
- More than 90% of PWB are UL-94 V-0 rated



Tetrabromobisphenol A (TBBPA)

www.albemarle.com

- Flame retardant of choice for more than 30 years
- Used in epoxy-based PWB
- Reactive flame retardant
- Once reacted TBBPA, is chemically incorporated into the backbone of the epoxy resin



Glycidylether of BPA

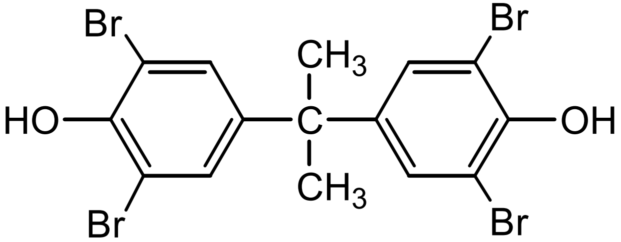
TBBPA

TBBPA-Advanced Resin
n, m > 0

ALBEMARLE™

Tetrabromobisphenol A (TBBPA)

- Benefits
  - After reaction with the epoxy resin, TBBPA is incorporated into the backbone of the epoxy resin
  - Stable Aromatic Bromine
  - High Purity
  - Low Ionic Content
  - Polymers based on this product have Excellent Electrical Properties



SAYTEX® CP-2000 Flame Retardant

Concerns With Flame Retardants

- There are concerns with the detection of low levels of various chemicals in the environment and human tissues
- This has led to the assessment of potential environmental or human health effects of numerous high production volume chemicals

It is important to remember: Detection ≠ Risk

EU Risk Assessment (RA)

www.albemarle.com

- The most comprehensive assessment of chemicals' environmental and human health impacts
- This examines all aspects of a chemical
- Products are assessed individually, not as a class
- If RA determines that risk reduction is necessary, then a Risk Management Program is developed

Four possible outcomes of an EU risk assessment:

Further studies needed

Approved as Safe

Risk Reduction Measures

Ban

ALBEMARLE™

TBBPA EU Risk Assessment Expected Timeline

March 2005

Final Human Health Report

- TBBPA is safe
- Consumer exposure is negligible

June 2006

Updated Environmental Risk Assessment Report

March 2007

Final review Environmental Report by EU Authorities

After March 2007

Finalization Risk Assessment Report

4th Quarter 2007

Final risk reduction strategy

Remaining Studies

Determine Risk Reduction Strategy

TBBPA EU Risk Assessment (RA) Human Health Section

- Human Health Section
  - RA was concluded in December 2004
  - Final conclusion: **no risks identified and no need for risk reduction measures**
  - Final report on Human Health RA published on ECB website & the conclusions will soon be published in the Official Journal http://ecb.jrc.it/esis/esis.php?PGM=org

  - SCHER (Scientific Committee on Health & Environ-mental Risks) opinion confirmed RA conclusions
  - Study from the University of Wurzburg (under EU Fire) also confirmed these conclusions

TBBPA EU Risk Assessment (RA) Environmental Section

www.albemarle.com

- Environmental Section
  - Still in progress, with completion expected in March 2007
  - Current Risk Assessment for reactive use indicates no risk reduction measures are foreseen, provided that sewage sludge is not spread on agricultural soil

  - TBBPA is classified **R50/53**, very toxic to aquatic organisms
  - This classification does not affect the reactive use of TBBPA as it forms part of the polymer backbone structure

  - EU Authorities agreed that TBBPA is not a Persistent, Bioaccumulative, Toxic (PBT) chemical

ALBEMARLE™

TBBPA – Additional Study

- CREDO Study
  - The EU Research Cluster on endocrine disruption, CREDO, announced results of long-term exposure studies on fish
  - Three studies on estuarine flounders with long-term exposure to TBBPA were performed
  - The conclusions were
    - **“no major endocrine effects found in fish”**
    - **“general health and toxicity parameters were not affected”**

EU REACH Directive

*R*egistration, *E*valuation and *A*uthorization of *Ch*emicals

- The REACH proposal will affect all of the chemical industry by requiring registration of all existing and future new substances with a new European Chemicals Agency
- All substances will have to go through one or more stages of the REACH process, which include: Registration, Evaluation, Authorization, & Restriction
- REACH entry into force is June 2007
- Registration of substances
  - >1,000 tonnes before Dec 2010
  - >100 tonnes before June 2013
  - >1 tonnes before June 2018

REACH – Impact on TBBPA

- TBBPA is a high volume substance (>1,000 tonnes)
- For TBBPA there will **not be** further data generation as all necessary data has been developed for the RA
- The results of the RA and risk reduction will be taken into account
- TBBPA is **unlikely to undergo further restrictions** under REACH
- TBBPA is not a PBT or CMR, and would **not** have to go through Authorization

EU RoHS Directive

TBBPA is not included in the RoHS Directive

Banned substances

Pb Penta-BDE

PBBs Cd

Octa-BDE Hg

Cr(VI)

TBBPA can satisfy RoHS Lead-Free solder requirements and is used commercially in lead-free laminates

EU WEEE Directive

- The EU Waste Electrical & Electronic Equipment (WEEE) Directive was put in place to deal with the rising amount of Electrical & Electronic waste
- This directive calls for selective treatment of components containing various materials, including printed circuits boards and BrFR plastics
- The directive requires separation of all PWB greater than 10 cm^2, regardless of whether they contain P, Al, Br, Cl, N, C, or any other element

EU WEEE Directive

- This requirement is fulfilled when the WEEE plastics are treated (recovered, recycled, thermally disposed, etc..) together with other wastes
  - An example of this is the joint recovery of materials (PWB, plastics containing BFR, with other materials) for energy recovery processes that are currently practiced in the EU

Other Regulatory Issues

www.albemarle.com

- Sweden
  - In Sept 2005, the Swedish Government requested KEMI to evaluate a potential ban on TBBPA
  - In March 2006, KEMI advised Swedish Government to await outcome of EU Risk Assessments:

    "*A comprehensive national ban would have <u>severe adverse practical & economic consequences</u> for society. A ban that does not make it possible to use TBBPA in the manufacturing of printed circuit boards for electronics would most probably result in the manufacturing & importing of most electronic products coming to a halt. All electronic products contain circuit boards.* ***Nor would a ban covering this use of TBBPA lead to any known benefits to health & the environment***."
  - A decision has not been made on whether the Government will propose a national ban

ALBEMARLE™

Other Regulatory Issues

- Norway
  - The SFT (Environmental Administration) is considering to draft a proposal to restrict TBBPA
  - The SFT has suggested that this type of restriction could go against the principle of free movement of goods
  - No formal proposal or consultation yet
  - No timing indicated

End-of-Life

- Main End-of-Life (EOL) outlet is to smelters
- PWB in Copper and Precious Metal Smelters
  - Source of energy recovery (replacing cokes)
  - Reducing agent for the metals
  - Most economical EOL scenario
  - Currently practiced safely
  - One-sixth of energy needed to produce copper from recycled material rather than from ore
- Several trials have shown that the addition of WEEE plastics to the smelting process provides energy for the smelting process without causing problems

Voluntary Emission Control Action Program (VECAP)

www.albemarle.com

Overview

Voluntary – producer and user implemented

Emissions – identify sources of emissions

Control – adjust procedures to minimize emissions

Action – dynamic, continuous improvement

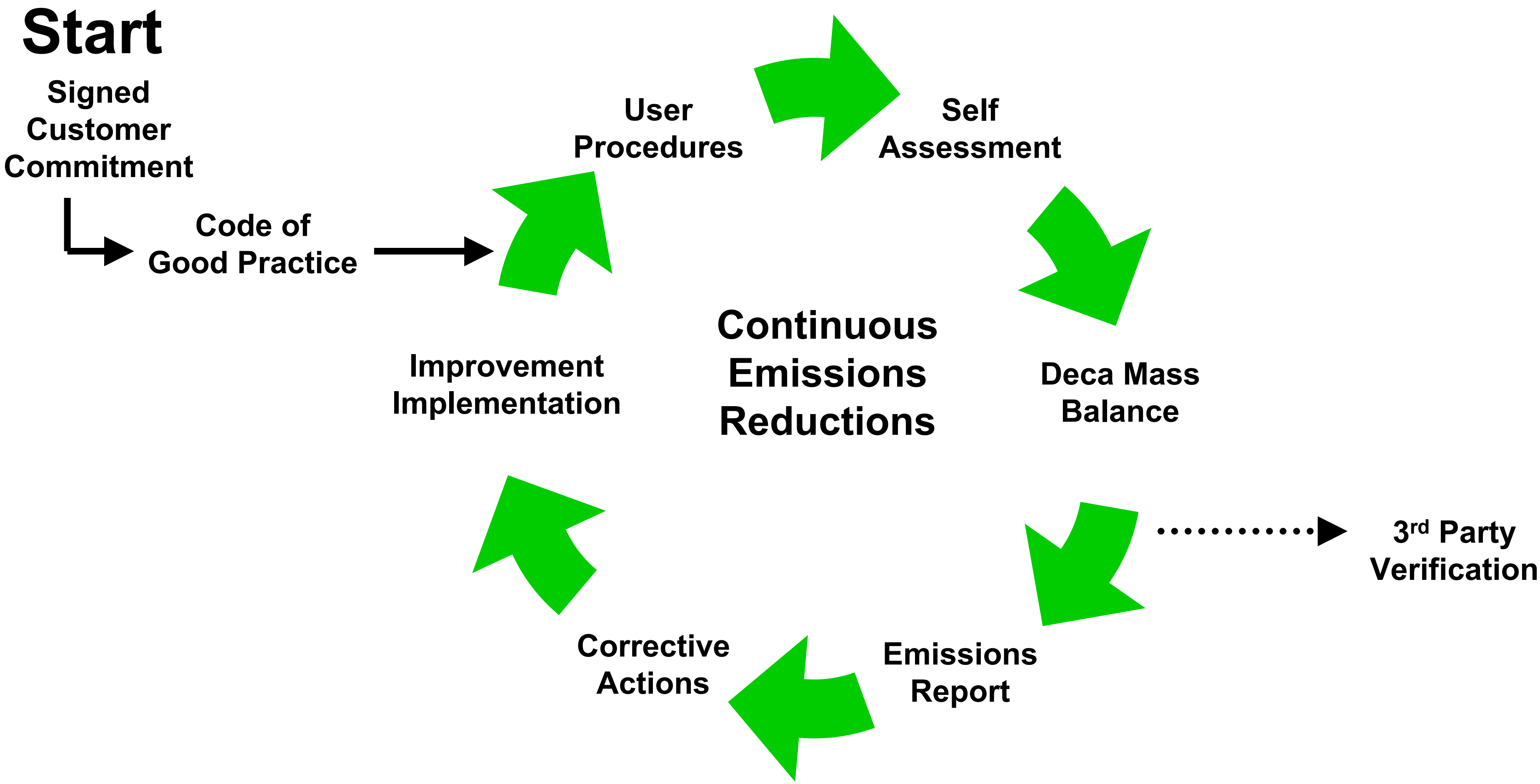
Program – written program with focus on Best Practices

- The program started with Deca-BDE in 2005
- Other flame retardants are now being included

After 1 yr, UK textile industry reduced Deca-BDE emissions to water from textile operations by 75%

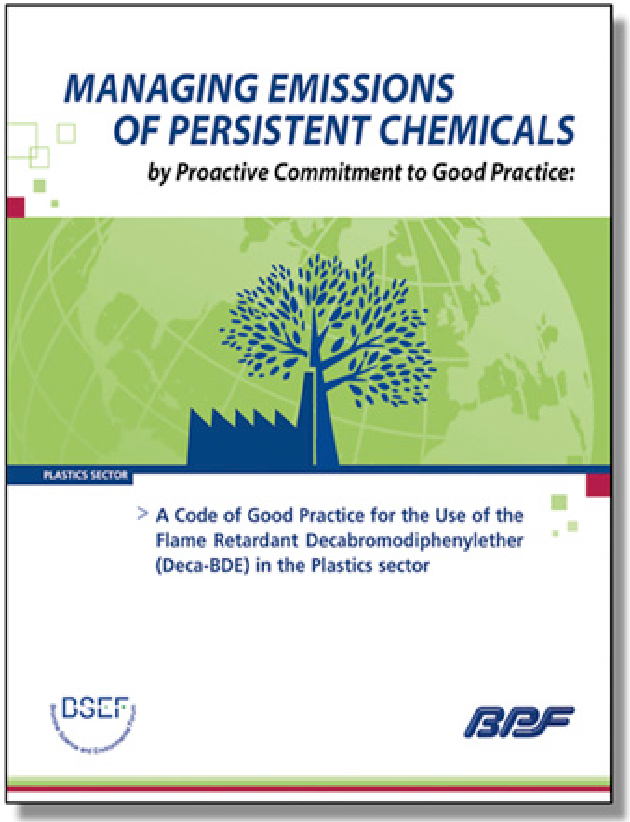
The Mechanics of VECAP

VECAP Flow Diagram



VECAP and TBBPA

- Aims to control emissions of substances through a mass balance approach
- Working in partnership with downstream users to implement emissions reduction first for additive use of TBBPA as higher priority based on RA results
- EBFRIP is currently defining the emissions baseline for additive use of TBBPA in Europe



ALBEMARLE™

TBBPA and EU Eco-Labels

- TBBPA for use in printed circuit boards is allowed under all of these various eco-labels:
  - **EU Eco-flower** (EU Commission) - Product groups include portable and personal PCs and TVs
  - **Blue Angel** (Germany) - Product groups include PCs, printers & copiers
  - **Nordic Swan** (Norway, Sweden, Iceland and Finland) - Product groups include PCs, copiers & fax
  - **TCO** (Sweden) - Product groups include PCs, printers, portables, notebooks, displays

Flame Retardant Options for PWB

- Environmental, health, safety, and performance aspects of flame retardant options for PWB are being evaluated

- Projects to compare flame retardant choices for Printed Wiring Boards (PWB)
  - US EPA DfE Electronics Partnership, *“Flame Retardants in Printed Circuit Board”*
    - Identify and evaluate environmental and human health and safety aspects of commercially available flame retardants used in FR-4 PWB
    - Determine the potential hazards and potential exposures throughout the life cycle - manufacture, use, and incineration or burning at EOL (also understand combustion products)

Flame Retardant Options for PWB

- iNEMI technical feasibility study of halogen free electronics
  - Will look into mechanical performance and reliability of PWB containing different flame retardants

- High Density Packaging User Group (HDPUG) comprehensive guidelines on halogen free PWB
  - Will assemble guidelines and product databases (either PWB or Components)

Conclusions

www.albemarle.com

- Tetrabromobisphenol A (TBBPA) is the flame retardant of choice for FR-4 Printed Wiring Boards (PWB) – over 30 years of use
- There are no restrictions on the use of TBBPA
- The EU Risk Assessment currently identifies no risks for TBBPA in PWB
- Several programs have been initiated to investigate the environmental, health, safety, and performance aspects of flame retardants for use in PWB

Conclusions

www.albemarle.com

- PWB containing TBBPA have an efficient and economical End-of-Life option that is already in place – smelting to remove valuable copper and precious metals
- The PWB laminate is a source for energy recovery (replacing cokes) and a reducing agent for the metals
- The Voluntary Emissions Control Action Program (VECAP) allows industry an excellent opportunity demonstrate responsible use of TBBPA and insure that it is kept out of the environment

ALBEMARLE™

More Information on the Web…

www.albemarle.com

www.albemarle.com	Albemarle Corporation
www.bsef.com	Bromine Science and Environmental Forum
www.fire-safety.net	American Fire Safety Council
www.firemarshals.org	National Assoc of State Fire Marshals
www.acfse.org	European fire safety coalition
www.ebfrip.org	European brominated flame retardant industry

ALBEMARLE™