Alternatives Assessment Examples Review

Document Title: Flame Retardants in Printed Circuit Boards: Final Report

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Purpose of the Report: U.S. EPA's DfE program and the electronics industry convened a partnership to identify and evaluate conventional and new flame retardants on their environmental, human health and safety, and environmental fate aspects in the application of printed circuit boards.

Report Summary: The report evaluates 10 flame retardants and resins as potentially viable options for Flame Resistant 4 (FR-4) laminate materials used on printed circuit boards. It helps the electronics industry consider human health and environmental impacts along with the cost and performance of circuit boards when evaluating alternative flame retardants and technologies used in printed circuit board applications. It incorporates hazard assessment, exposure scenario considerations, and life cycle thinking when evaluating the alternatives.

Key Findings:

Product requirements: Chapters 2 and 3 contain a detailed discussion of FR-4 laminates and the flame-retardant chemicals used in them, including processes, general characteristics, classifications, and functions.

Identification of alternatives: The report identifies commercially available reactive and additive[1] flame-retardant chemicals and resins for FR-4 laminate materials for printed circuit boards based on the general characteristics of flame retardants and associated mechanisms of flame retardancy.

Identification of relevant factors: Chapter 2's discussion on the FR-4 laminates and the halogen-free laminate market provides an example where marketplace data is used as a surrogate for assessing potential exposure. Chapter 4 has a well-documented discussion on some toxicological and ecological endpoints (listed in the Safer Consumer Product regulations) and their associated evaluation criteria. The endpoints discussed are carcinogenicity, genotoxicity, reproductive toxicity, developmental toxicity, neurotoxicity, dermatoxicity, respiratory toxicity, ocular toxicity, acute and chronic aquatic toxicity, environmental persistence, and bioaccumulation.

Human health hazard: Chapter 4 discusses the methodology used to evaluate human health endpoints, environmental toxicity and fate endpoints, and endocrine activity. It discusses hazard designations and the

[1] *Reactive flame retardants are incorporated into polymers via chemical reaction; additive flame retardants are incorporated into polymers via physical mixing.*

criteria used to assign them, data sources, physical and chemical properties, environmental transport, and biodegradation. The executive summary has a good example of a table summarizing the screening level hazard for reactive flame-retardant chemicals and resins.

Exposure: Exposure assessment is conducted based on the concept of "functional use." This approach assumes exposure scenarios related to chemical use are similar across different chemicals when they fulfill the same chemical function in the product. Guidance is provided on exposure assessment considerations for future follow-on analyses, but no quantitative estimates are provided in the report itself. For the conventionally used flame retardant, tetrabromobisphenol A (TBBPA), readers are referred to the 2003 European Union Risk Assessment Report for a quantitative exposure assessment. For the other four reactive flame retardants considered, exposure is anticipated during manufacture of the flame retardant or resin and, for resins only, during the manufacture of the laminate. For the five additive flame retardants, exposure is anticipated during all life cycle stages. Qualitative exposure statements are provided for each flame retardant, indicating the relevant life stages, influence of functionality (mono, di, or tetra) and physicochemical properties (volatility, water solubility), and release mechanisms (fugitive dust, shredder dust, leaching, smelting). These statements allow relative comparisons of the alternatives. As a major complication, the report states that "it is important to note that many of these flame-retardant chemicals must be used together in different combinations to meet the performance specifications."

Data gaps and uncertainties: Chapter 7 discusses data gaps in the full characterization of chemicals included in this assessment and how a decision can be made with consideration of these uncertainties. It also clearly documents the hierarchy of data adequacy and data quality. Section 4.4.2 discusses the application of a structure analysis relationship and expert judgment approach to fill some hazard endpoint data gaps.

Decision-making: Chapter 7 outlines appropriate attributes for a decision-maker to consider when determining trade- offs of select alternatives. It states that higher preference is given to human health and environmental hazards over the other considerations for the study. A detailed discussion of data gaps and uncertainties is also included.