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Chemical alternatives assessment: The case of flame retardants

Gregory J. Howard *

Department of Environmental Studies, Dickinson College, PO Box 1773, Carlisle, PA 17013, USA

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ABSTRACT

Decisions on chemical substitution are made rapidly and by many stakeholders; these decisions may have a direct impact on consumer exposures, and, when a hazard exists, to consumer risks. Flame retardants (FRs) represent particular challenges, including very high production volumes, designed-in persistence, and often direct consumer exposure. Newer FR products, as with other industrial chemicals, typically lack data on hazard and exposure, and in many cases even basic information on structure and use in products is unknown. Chemical alternatives assessment (CAA) provides a hazard-focused approach to distinguishing between possible substitutions; variations on this process are used by several government and numerous corporate entities. By grouping chemicals according to functional use, some information on exposure potential can be inferred, allowing for decisions based on those hazard properties that are most distinguishing. This approach can help prevent the "regrettable substitution" of one chemical with another of equal, or even higher, risk.

1. Introduction

Chemical alternatives assessment (CAA) is one application of the broader process of alternatives assessment. The CAA approach is being used by the United States Environmental Protection Agency to inform safer substitution decisions, and other government entities (including the European Union) are beginning to require similar processes. Several companies and trade organizations use CAA to inform their own internal chemical substitution decisions. This paper will describe the CAA methodology, demonstrating its utility for the specific case of flame retardants, and highlighting some of the differences between alternatives assessment and risk assessment frameworks. In particular, the preference for an alternatives assessment or a risk assessment approach may derive in part from a stakeholder's views about the efficacy of exposure controls in managing risk.

1.1. Flame retardants

Flame retardants (FRs) pose numerous risk management challenges. FRs belong to several classes of chemistry and structure; are produced in very high volumes; and, out of functional necessity, are typically designed to be persistent. In many applications, including home furnishings and consumer electronics, consumers have direct exposure to FRs in the product itself or as the FRs migrate out of the product. Many FRs, notably the polybrominated diphenyl ethers (PBDEs), have been found in environmental and biological monitoring, making them of interest to nongovernmental health and environment organizations (NGOs) as well as to regulators. The largest set of data is available for PBDEs, due to their relatively early identification and very widespread use; but in recent years, replacement FRs are reaching the levels of ubiquitous exposure that first raised flags for PBDEs a decade ago. If these substitutions have lower hazard, they may be expected to pose less risk to consumers. Most replacements, however—with a few exceptions like tris(1,3-dichloro-2-propyl) phosphate (TCDPP)—are of more recent origin and hence much less studied; indeed, most new industrial chemicals are unlikely to be studied for toxicity in any rigorous way (Grandjean and Landrigan, 2006). Information on exposure may be even less common. Egeghy et al. (2012) report that only 20% of chemicals for which hazard data exists have any exposure information at all—and in most of these cases, available exposure information consists of very basic descriptors like production volume.

The use of pentabrominated diphenyl ether (pentaBDE) in foam furnishings has been largely driven by California's Technical Bulletin 117 (1975), which requires small (candle-sized) open flame testing of uncovered foam samples, necessitating the use of flame retardants (BHF, 2000). Because manufacturers prefer not to reformulate products for separate markets, TB117 appears to have become a *de facto* national standard (Stapleton et al., 2012). (In November 2013, California approved revisions to the TB117 standard. The new standard replaces the flame test with a

* Tel.: +1 (717) 245 1527.
E-mail address: howardg@dickinson.edu

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smolder test, which will allow, but not compel, manufacturers to reduce FR loads in furniture foam; see BHFTI, 2013.) PentaBDE was phased out voluntarily by the only US manufacturer, Great Lakes (now Chemtura), under pressure from EPA and environmental NGOs, at the end of 2004 (USEPA, 2012). Shortly thereafter, EPA published a Significant New Use Rule to prevent future use of pentaBDE in this market segment (although the rule does not restrict import of products containing pentaBDE).

This phase-out appears to have been effective in reducing consumer exposure to pentaBDE, according to measurements in house dust (Dodson et al., 2012) and in samples taken from furniture (Stapleton et al., 2012). The most commonly used alternatives have been TDCPP, which had seen widespread use in concert with pentaBDE before the phase-out, and Firemaster 550 (FM550), a blend of two brominated and two phosphate-based FRs (Stapleton et al., 2012).

As part of EPA's action on pentaBDE, EPA's Design for the Environment (DfE) branch convened the Furniture Flame Retardancy Partnership (FFRP) in 2003 to assess alternatives to pentaBDE for use in furniture foam (USEPA, 2005). This project was an early attempt to use alternatives assessment to provide important hazard information on all known available alternatives, including TDCPP and FM550.

2. Discussion

2.1. Chemicals alternatives assessment

"Alternatives assessment" encompasses a wide-range of decision-making tools and has been described elsewhere (O'Brien, 2000). More specifically, chemical alternatives assessment (CAA), as described by Lavoie et al. (2010), applies a hazard framework to inform decision-making around chemical substitution; this definition will be used here. There are a number of variations on alternatives assessment processes, but they share some key features.

- The key aim of CAA is to avoid "regrettable substitution", that is, the unwitting selection of an alternative that poses equal or higher risk.
- CAAs compare numerous options at once, whereas risk assessment typically treats chemicals singly (often in greater depth).
- CAAs are intended to be quicker and simpler than risk assessments, generally by focusing on hazard evaluation, avoiding the complexities of exposure assessment (although the addition of information on exposure and persistence may help prioritize alternatives).
- CAAs, and AAs in general, are intended to lower risks by encouraging selection of chemicals and processes with the lowest available hazard profiles. This contrasts with a more traditional risk assessment approach of keeping risks below a threshold by managing exposures.

Most descriptions of alternatives assessment processes also stress the importance of process transparency, the value of stakeholder participation, and the goal of continuous improvement (Rossi et al., 2006).

Alternatives assessment can be seen as an overarching approach to decision making, within which specific tools like hazard-oriented CAA and life-cycle assessment are applied to evaluate alternatives along endpoints of interest (Elizabeth Sommer, USEPA Design for the Environment, personal communication). AAs performed by different users with different needs might address any of a diverse set of endpoints ranging from physical and chemical hazards, to fate and transport in the environment, to life-cycle impacts. Given the range of endpoints, and of tools used to distinguish among them, AA is not an easily defined process, but varies in depth and complexity. Even within the realm of hazard, often considered to be the principal concern of AA, there are a large number of human health and environmental endpoints that might be considered. Tools applied to assess an endpoint might range from a comparison with various "red lists" of chemicals of concern, to a literature-based hazard screen, or even to a comprehensive evaluation of risk. Regardless of this variety, however, and fundamental to the idea of alternatives assessment, any AA should first start with an assessment of the need for the chemical function under study: For example, assessing whether FRs added to products are effective in improving fire safety characteristics or in increasing escape times.

The DfE Alternatives Assessment process is an example of a hazard-oriented CAA process for informing chemical substitution decisions; this approach is primarily concerned with human health and environmental toxicity endpoints over the entire lifecycle. The DfE process examines endpoints for human and environmental toxicity as well as persistence and bioaccumulation (see Table 1). DfE's goal is to provide information to support decision-making by other stakeholders, especially manufacturers; its assessments focus on describing alternatives to chemicals which have been identified by other actors, whether within EPA or internationally, for possible regulation or substitution. (EPA does not use the CAA methodology to make regulatory decisions.) For example, hexabromocyclododecane (HBCD), for which DfE published a draft alternatives assessment in the fall of 2013, is not yet the subject of regulation in the US, but has been listed by the EU as a Substance of Very High Concern (SVHC), requiring US manufacturers to find an alternative to stay competitive in the global market. DfE's CAAs do not make recommendations about specific choices, in part because considerations of performance, efficacy, and cost fall outside the branch's expertise, and are best left to manufacturers. However, DfE's process does include extensive consultation with chemical and product manufacturers to ensure, as far as possible, that all appropriate chemicals are assessed, and that those chemicals assessed are appropriate to the functional use class in terms of efficacy and practicality. In this sense, the scoping of the DfE CAA incorporates basic information about performance and feasibility.

Within the category of flame retardants, DfE has published, or is in the process of writing, assessments of alternatives to pentaBDE

Table 1
Human and environment endpoints evaluated by DfE (USEPA, 2011; 2013b). (While DfE sometimes considers additional endpoints, specific criteria are available for those listed here.)

Human health effects
Acute mammalian toxicity
Carcinogenicity
Mutagenicity/genotoxicity
Reproductive toxicity
Developmental toxicity (including developmental neurotoxicity)
Neurotoxicity
Repeated-dose toxicity
Respiratory sensitization
Skin sensitization
Eye irritation/corrosivity
Skin irritation/corrosivity
Endocrine activity
Environmental toxicity and fate
Aquatic toxicity: Acute
Aquatic toxicity: Chronic
Environmental persistence
Bioaccumulation
Additional endpoints
Physical hazards
Other forms of ecotoxicity: Avian; bees

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