Designing and delivering strategic solutions for green chemicals, sustainable materials and environmentally preferable products

Moving to Safer Alternatives
Fire Retardant Dilemma Symposium
UC Berkeley, January 30

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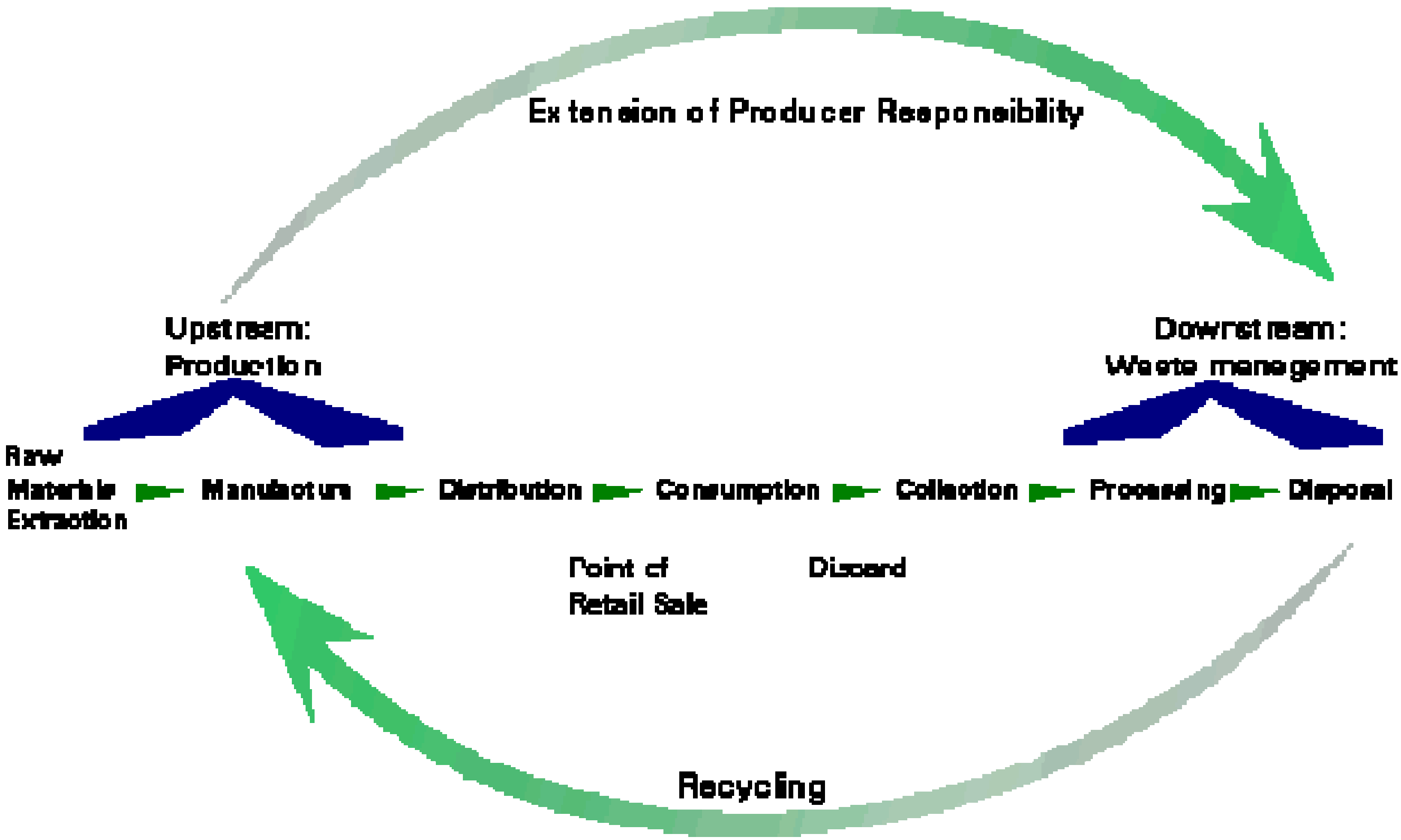
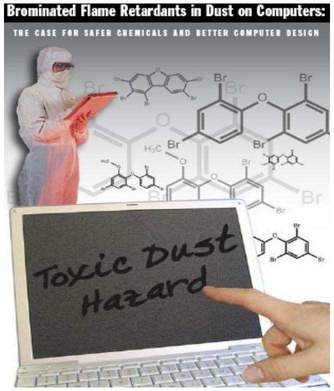
Establishing Extended Producer Responsibility (EPR): exposure to halogenated chemicals emerged as a critical issue (focus on BFRs & PVC)





Major catalysts for focus on halogen free electronics

- Responsibility for end of life management of products.
- Implementation of existing regs (RoHS I) and anticipation of new regs (RoHS II, REACH, state policy bans).
- Expectation of increased demand for greener products (institution purchasers specifying halogen free).
- NGO campaigns documenting dioxin and BFR contamination and exposure.
- Toxicity of halogenated FR alternatives

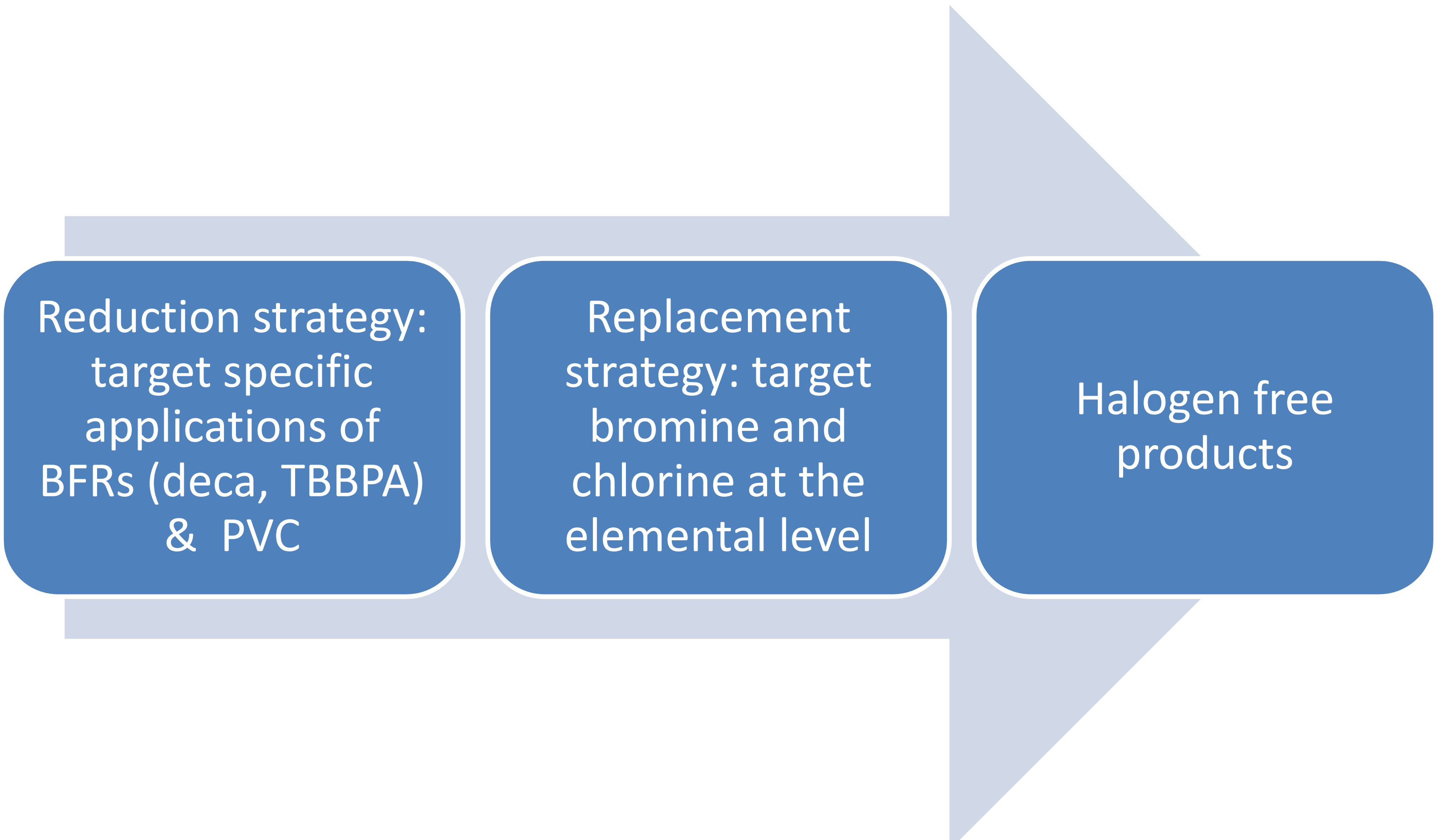
The path towards halogen free electronics

1. Corporate commitment to replacing brominated and chlorinated compounds
2. Establish strong bromine/chlorine supply chain standards
3. Secure policy to level the playing field
4. Establish tools and resources that promote safer substitution, ie design out flame retardants and or use inherently safer chemicals

1. Corporate progress towards halogen free (major computer and television companies)

Approach	Manufacturer
Restrict all chlorine/bromine based compounds in all products	Apple (almost fully transitioned out)
Restrict BFRs in all products	Acer & Lenova(2009), Samsung, Fijitsu Siemens &LG (2010), Dell (date uncertain)
Restrict PVC in all products	Acer & Lenova (2009), Samsung, LG &Sharp (2010), Dell (date uncertain)
Partial restriction of PVC and BFRs (some applications, certain compounds)	Hewlett Packard, Phillips, Toshiba, Sony, Panasonic

2. Supply chain standards



	Approach	Analysis
Strictest	0 ppm elemental Br and Cl (Greenpeace position)	given residue contamination issues in the supply chain, not currently possible to engineer to this specification for most suppliers, common test methods do not detect below 50 ppm
Strict	900ppm elemental Br and Cl (Apple spec)	implementable, verifiable, possible to engineer, but still difficult to get legislator/ supplier buy in
Loose	900ppm compound forms of Br and Cl in flame retardant and PVC applications only (IPC proposed standard)	implementable, difficult to independently verify and measure, reliant on supply chain declarations, Br and Cl continues to be used in large volumes, possible to get legislator/supplier buy-in
Loosest	1000ppm for TBBP-A and Phthalates (RoHS I approach on PBBs & PBDEs)	implementable, difficult to independently verify (almost impossible to verify phase out of reactive TBBP-A), possible to engineer, possible to get legislator/supplier buy-in

Why Apple standard is so significant

- Acknowledges the risk of all chlorinated and brominated compounds in electronics (very strong message to the chemical industry) and their use in many different applications.
- Establishes a threshold that closes the door on intentionally added BFRs and all uses of PVC (BFRs perform typically at a 50,000 ppm level, reactive TBBP-A cannot be verified at compound level).
- BFRs cannot be substituted with other halogenated flame retardants.
- Can be independently verified and measured (does not rely on supply chain declarations)
- Leverages best practice (elemental approach established in RoHS I for lead)

3. Establishing policy: REACH vs. RoHS?

1. Keep the REACH process separate from the RoHS Review.

We are strong supporters of REACH as the overarching chemicals regulation. However for chemicals regulation in the electronics sector, RoHS is the most appropriate legal instrument. REACH will be a very slow roll out of chemicals policy for all sectors not just the electronics industry. It is not a matter of double regulation: REACH regulation for these particular applications is not yet in place, while RoHS is.

2. Strengthen the RoHS Directive.

As a priority, a revised RoHS should target the phase out of elemental bromine and chlorine in electronic products as well as the phthalates used widely in PVC plastics. All these chemicals are known to disrupt the reproductive and hormonal systems and present exposure risks to workers in manufacturing and recycling plants.

Substitution Principle (foundation of RoHS)

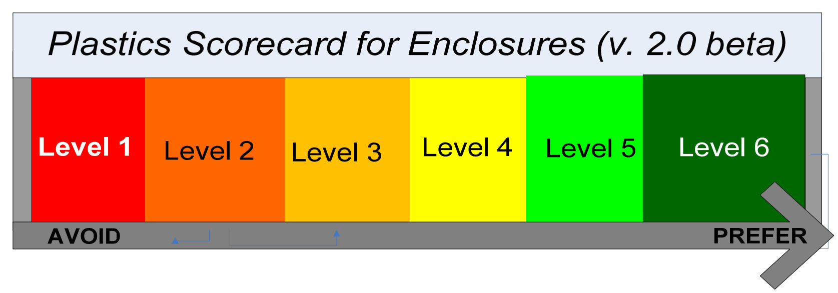
Whereas:

(6) "… **the most effective way of ensuring the significant reduction of risks** to health and the environment … is the **substitution** of those substances in electrical and electronic equipment **by safe or safer materials**."

(11) "**Exemptions from the substitution requirement** should be permitted **if** **substitution is not possible** … **or** if the **negative** environmental or health **impacts caused by substitution** are likely to **outweigh the** human and environmental **benefits** of the substitution."

4. Establish tools and resources

- Tools for institutional purchasers
  - Purchasing specifications
  - EPEAT—green product registration
- Tools to assess the inherent hazard of chemicals and promote green chemistry
- Tools to evaluate alternative materials



THE **GREEN SCREEN** FOR SAFER CHEMICALS:

Evaluating Flame Retardants for TV Enclosures

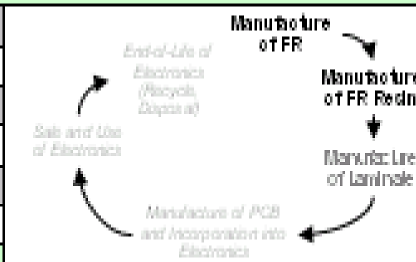
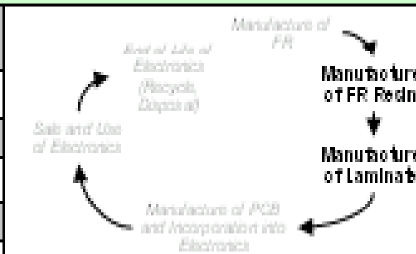
CLEAN PRODUCTION ACTION

VERSION 1.0

USEPA DfE Flame Retardancy Partnerships

Furniture Foam (pentaBDE) and Printed Circuit Boards (TBBPA)

DRAFT ONLY

Chemical	CASRN	Human Health Effects: Acute Toxicity	Skin Sensitizer	Cancer Hazard	Immunotoxicity	Reproductive	Developmental	Neurological	Systemic	Genotoxicity	Aquatic Toxicity: Acute	Chronic	Environmental: Persistence	Bioaccumulation	Exposure Considerations: Availability of flame retardants (FRs) throughout the lifecycle for reactive and additive FRs chemicals and resins
Reactive Flame Retardant Chemicals[2]															
Tetrabromobisphenol A (TBBPA) (Albemarle, Chemtura, and others)															
TBBPA	79-94-7	L	L	*L*	L	L	M	L	L	L	H	*H*	M	L	
DOPO (6H-Dibenz[c,e][1,2] oxaphosphorin, 6-oxide) (Sanko Co., Ltd. and others)															
DOPO	35948-25-5	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	L	*M*	*M*	*L*	*L*	
Fyrolflex PMP (Aryl alkylphosphonate) (Supresta)															
Fyrolflex PMP	Proprietary	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*	
Reactive Flame Retardant Resins[2]															
Reaction product of TBBPA - D.E.R. 538 (Phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo-, polymer with (chloromethyl)oxirane and 4,4'-(1-methylethylidene)bis[phenol]) (Dow Chemical)															
D.E.R. 538	26265-08-7	*L*	M	*M°*	*L*	*M°*	*M°*	*L*	*L*	M	*L*	*L*	*M*	*L*	
Reaction Product of DOPO - Dow XZ-92547 (reaction product of an epoxy phenyl novolak with DOPO) (Dow Chemical)															
Dow XZ-92547	Proprietary	*L*	M	*M°*	*L*	*M°*	*M°*	*L*	*L*	*M°*	*L*	*L*	*H*	*L*	
Reaction product of Fyrolflex PMP with bisphenol A, polymer with epichlorohydrin (Representative Resin)															
Representative Fyrolflex PCB Resin	Unknown	*L*	*L*	*M°*	*L*	*M°*	*M°*	*L*	*L*	*M°*	*L*	*L*	*H*	*L*	

Comparing emissions from combustion testing

TABLE 3: **Threshold Values for Each Chemical Hazard Included in the Green Screen**

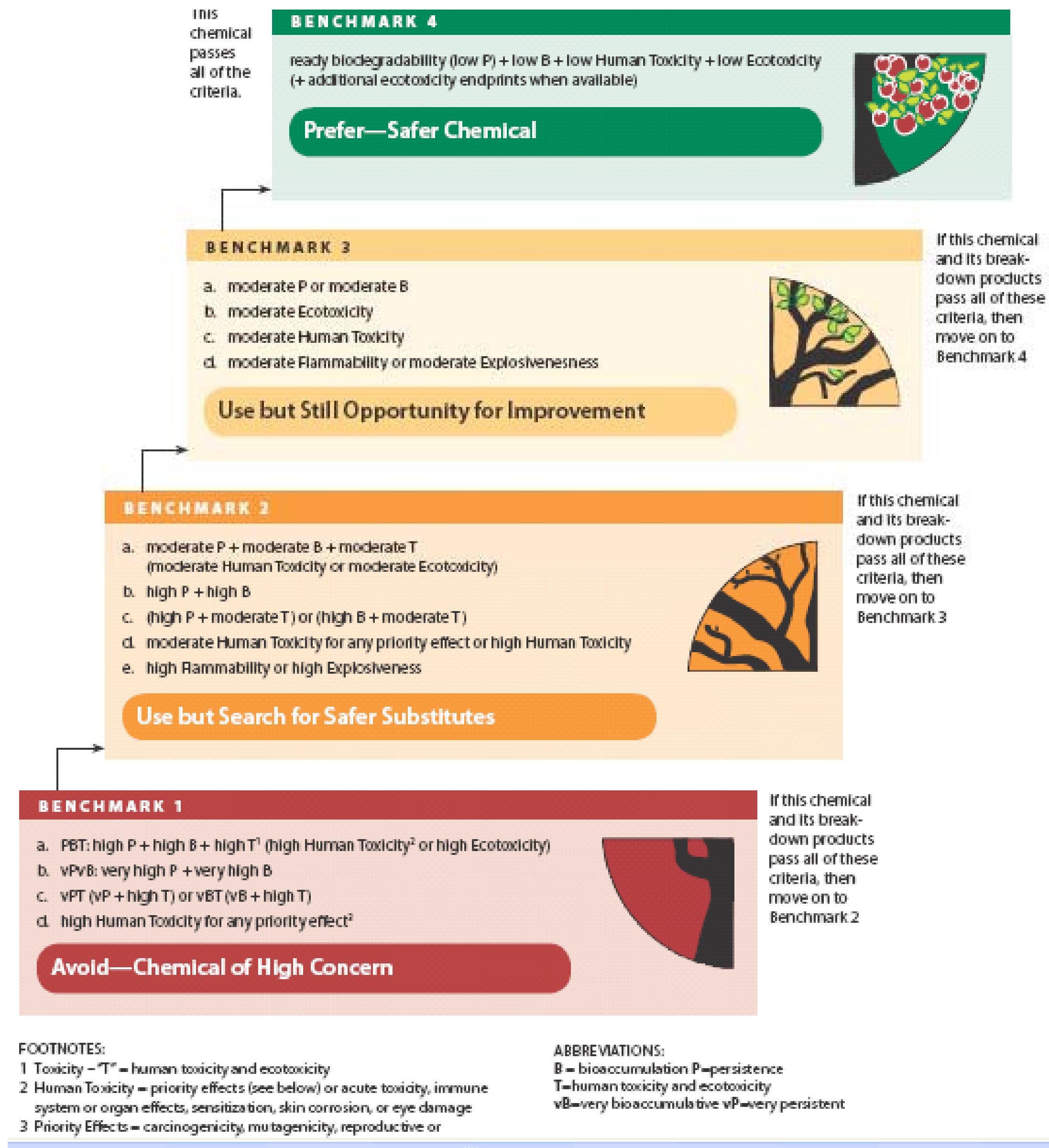
Hazard	Very High (v)	High (H)	Moderate (M)	Low (L)
Environmental Fate				
Persistence—P (half-life in days)[1]	• Soil or sediment >180 days; or • Water >60 days	• Soil or sediment >60 to 180 days; • Water >40 to 60 days; or • Potential for long-range environmental transport	• Soil or sediment 30 to 60 days; or • Water 7 to 40 days	• Soil or sediment <30 days; • Water <7 days; or • Ready bio-degradability
Bioaccumulation Potential—B[1]	• BCF/BAF >5000; or • Absent such data, log K_{ow} >5	• BCF/BAF >1000 to 5000; • Absent such data, log K_{ow} >4.5-5; or • Weight of evidence demonstrates bioaccumulation in humans or wildlife	• BCF/BAF 500 to 1000; • Absent such data, log K_{ow} 4-4.5; or • Suggestive evidence of bioaccumulation in humans or wildlife	• BCF/BAF <500; or • Absent such data, log K_{ow} <4
Ecotoxicity				
Acute Aquatic Toxicity[1]		• $LC_{50}/EC_{50}/IC_{50}$ <1 mg/l; or • GHS Category 1	• $LC_{50}/EC_{50}/IC_{50}$ 1-100 mg/l; or • GHS Category 2 or 3	• $LC_{50}/EC_{50}/IC_{50}$ >100 mg/l
Chronic Aquatic Toxicity[1]		• NOEC <0.1 mg/l; or • GHS Category 1	• NOEC 0.1-10 mg/l; or • GHS Category 2, 3 or 4	• NOEC >10 mg/l
Human Health				
Carcinogenicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP known or reasonably anticipated to be human carcinogen; • OSHA carcinogen; • US EPA known/likely (probable); • California Prop 65; • IARC Group 1 or 2A; • EU Category 1 or 2; or • GHS Category 1A or 1B	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • US EPA suggested evidence (possible); • IARC Group 2B; • EU Category 3; or • GHS Category 2	• No basis for concern identified or • IARC Group 3 or 4
Mutagenicity/ Genotoxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • EU Category 1 or 2; or • GHS Category 1A or 1B	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2	No basis for concern identified
Reproductive toxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP Center for the Evaluation of Risks to Human Reproduction; • California Prop 65; • EU Category 1 or 2; or • GHS Category 1A or 1B	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2	No basis for concern identified
Developmental toxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP Center for the Evaluation of Risks to Human Reproduction; or • California Prop 65	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Endocrine Disruption*		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Draft List—Category 1 or 2; or • Japanese list	No basis for concern identified

TABLE 3: **Threshold Values for Each Chemical Hazard Included in the Green Screen** continued

Hazard	Very High (V)	High (H)	Moderate (M)	Low (L)
Neurotoxicity*		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Acute Toxicity (oral, dermal, or inhalation)		• LD_{50} <50 mg/kg bodyweight (oral); • LD_{50} <200 mg/kg bodyweight (dermal); • LC_{50} <500 ppm (gas); • LC_{50} <2.0 mg/l (vapor); • LC_{50} <0.5 mg/l (dust or mist); • US EPA Extremely Hazardous Substance List; or • GHS Category 1 or 2	• LD_{50} 50-2000 mg/kg bodyweight (oral); • LD_{50} 200-2000 mg/kg bodyweight (dermal); • LC_{50} 500-5000 ppm (gas); • LC_{50} 2-20 mg/l (vapor); • LC_{50} 0.5-5 mg/l (dust or mist); or • GHS Category 3 or 4	No basis for concern identified
Corrosion/Irritation of the Skin or Eye		• Evidence of irreversible effects in studies of human populations; • Weight of evidence of irreversible effects in animal studies; or • GHS Category 1 (skin or eye)	• Evidence of reversible effects in humans or animals; • GHS Category 2 or 3—skin irritation; or • GHS Category 2A or 2B—eye	No basis for concern identified
Sensitization of the Skin or Respiratory System		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • GHS Category 1—(skin or respiratory); or • Positive responses in predictive Human Repeat Insult Patch Tests (HRIPT) (skin)	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Immune System Effects		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Systemic Toxicity/Organ Effects (via single or repeated exposure)		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • GHS Category 1—organ/systemic toxicity following single or repeated exposure	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • GHS Category 2 or 3 single exposure; or • Category 2 repeated exposure	No basis for concern identified
Physical/Chemical Properties				
Explosive		• GHS Category: Unstable explosives or Divisions 1.1, 1.2, or 1.3	• GHS Category: Divisions 1.4 or 1.5	No basis for concern identified
Flammable		• GHS Category 1—Flammable Gases; • GHS Category 1—Flammable Aerosols; or • GHS Category 1 or 2—Flammable Liquids	• GHS Category 2—Flammable Gases; • GHS Category 2—Flammable Aerosols; or • GHS Category 3 or 4—Flammable Liquids	No basis for concern identified

Green Screen for Safer Chemicals: Benchmarks

- 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



Green Screen was Used to Assess Flame Retardants Commonly used in TV Casings

TABLE 7: **Green Screen Benchmarks for Phosphorous-based and DecaBDE Flame Retardants**

Chemical	CAS #	Reasons for Benchmark	Benchmark Achieved
DecaBDE and its breakdown products	1163-19-5	Breakdown products stop decaBDE at Benchmark 1: • pentaBDE = PBT, vPvB, vPT, vBT, and high concern for endocrine disruption—Benchmarks 1(a),(b),(c),(d) • octaBDE = vPT and high concern for developmental toxicity—Benchmark 1(c),(d)	Benchmark 1: Avoid—Chemical of High Concern
BPADP/BAPP and its breakdown products	181028-79-5	Breakdown product and formulation contaminant, bisphenol A, is of high concern for endocrine disruption—stopping BPADP at Benchmark 1(d)	Benchmark 1: Avoid—Chemical of High Concern
RDP and its breakdown products	125997-21-9	• Chemical constituents have: high persistence *or* high bioaccumulation and moderate/high toxicity (but not for priority effects)—stopping RDP at Benchmarks 2(a) and 2(c) • Breakdown product, phenol, has high systemic effects—stopping RDP at Benchmark 2(d)	Benchmark 2: Use <u>but</u> Search for Safer Substitutes

Who has applied the Green Screen?

- Government agencies in support of policies to identify and substitute chemicals of high concern
  - Flame retardants
  - Toys
- OEMs to ensure the availability of safer alternatives (flame retardants)
- Retailers to screen products for use by buyers
- Publications on green chemistry metrics

The Green Screen Method:

Currently Applying to FRs used with Printed Circuit Boards (DfE)

- Builds on USEPA Design for the Environment hazard assessment protocols
- Considers significant transformation products
- Expand hazard considerations (includes endocrine disruptors)
- Highly protective of human health and the environment
- Focuses on comparative hazard assessment across similar functional use (not risk assessment)
- Defines green chemicals
- Scientifically based
- Open, transparent and publicly available
- Drives continuous improvement and innovation

GREEN SCREEN FOR SAFER CHEMICALS

The Green Screen Approach:
Concurrent Strategies for Greening Chemical Inventories

Aim for the Top
Prefer chemical products that are fully assessed and that have low hazard and lifecycle benefits

Practice Informed Substitution
Process of continual improvement; toward more data and better understanding of what is green and sustainable

Bring up the Bottom
Screen all chemicals against criteria for adverse impacts to human health and the environment to move away from the use of the most hazardous chemicals

Today there are simply not enough alternative substances in the lower tier to serve as substitutes for chemicals of high concern. One leading green chemist claims that 65% of hazardous chemicals do not have green chemistry alternatives.

Ken Geiser, Comprehensive Chemicals Policies for the Future, November 2008

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