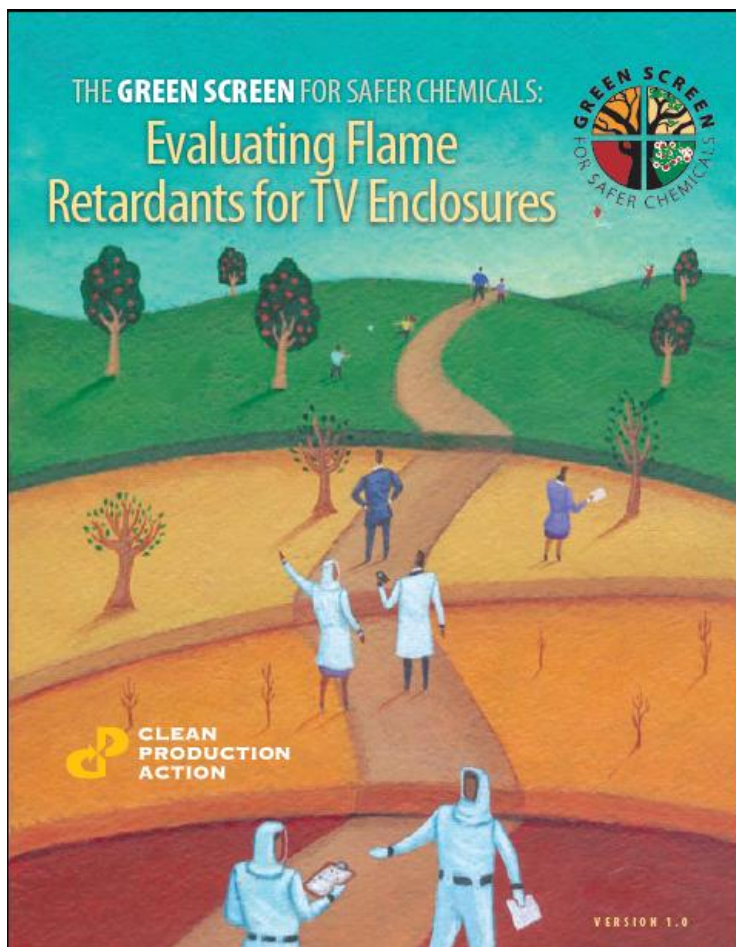


The Green Screen for Safer Chemicals: Meeting Today's Chemical Management Challenges with New Approaches and Collaborations



**Green Chemistry and
Commerce Council
May 4-6, 2009**

Clean Production Action
www.cleanproduction.org



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

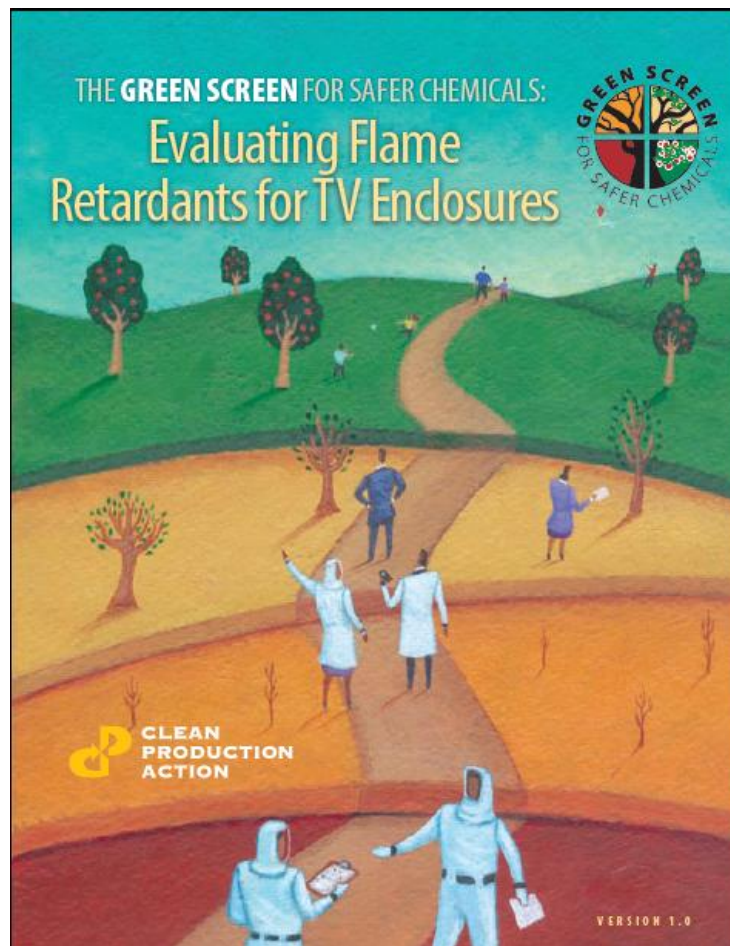
Bring up the Bottom

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

Which Flame Retardant is Better?

The Green Screen for Safer Chemicals v1.0

- Guidance for selecting greener chemicals
- Case Study: FRs used in television casings
 - decaBDE,
 - RDP
 - BPADP
- v2 under development



Download at: <http://www.cleanproduction.org/Green.Greenscreen.php>

Genesis of the Green Screen :

Builds on USEPA DfE Flame Retardancy Partnerships

DRAFT ONLY

| Chemical | CASRN | Human Health Effects | | | | | | | | | | Aquatic Toxicity | | Environmental | | Exposure Considerations | | |
|---|-------------|----------------------|-----------------|----------------|----------------|----------------|----------------|--------------|----------|----------------|-------|------------------|-------------|-----------------|--|-------------------------|--|--|
| | | Acute Toxicity | Skin Sensitizer | Cancer Hazard | Immunotoxicity | Reproductive | Developmental | Neurological | Systemic | Genotoxicity | Acute | Chronic | Persistence | Bioaccumulation | | | | |
| Reactive Flame Retardant Chemicals² | | | | | | | | | | | | | | | | | | |
| Tetrabromobisphenol A (TBBPA) (Abermarle, 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) (Sankyo 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 Resins² | | | | | | | | | | | | | | | | | | |
| Reaction product of TBBPA - D.E.R. 538 (Phenol, 4,4'-(1-methylethyldiene)bis[2,6-dibromo-, polymer with (chloromethyl)oxirane and 4,4'-(1-methylethyldiene)bis(phenol)] (Dow Chemical) | | | | | | | | | | | | | | | | | | |
| D.E.R. 538 | 26265-08-7 | L | M | M ⁰ | L | M ⁰ | M ⁰ | L | L | M | L | L | M | L | | | | |
| Reaction Product of DOPO - Dow XL-92547 (reaction product of an epoxy phenyl novolak with DOPO) (Dow Chemical) | | | | | | | | | | | | | | | | | | |
| Dow XL-92547 | Proprietary | L | M | M ⁰ | L | M ⁰ | M ⁰ | L | L | M ⁰ | 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 ⁰ | L | M ⁰ | M ⁰ | L | L | M ⁰ | L | L | H | L | | | | |

New

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 | <ul style="list-style-type: none"> • Soil or sediment >180 days; or • Water >60 days | <ul style="list-style-type: none"> • Soil or sediment >60 to 180 days; • Water >40 to 60 days; or • Potential for long-range environmental transport | <ul style="list-style-type: none"> • Soil or sediment 30 to 60 days; or • Water 7 to 40 days | <ul style="list-style-type: none"> • Soil or sediment <30 days; • Water <7 days; or • Ready biodegradability |
| Bioaccumulation Potential—B¹ | <ul style="list-style-type: none"> • BCF/BAF >5000; or • Absent such data, $\log K_{ow} >5$ | <ul style="list-style-type: none"> • BCF/BAF >1000 to 5000; • Absent such data, $\log K_{ow} >4.5$; or • Weight of evidence demonstrates bioaccumulation in humans or wildlife | <ul style="list-style-type: none"> • BCF/BAF 500 to 1000; • Absent such data, $\log K_{ow}$ 4-4.5; or • Suggestive evidence of bioaccumulation in humans or wildlife | <ul style="list-style-type: none"> • BCF/BAF <500; or • Absent such data, $\log K_{ow} <4$ |
| Ecotoxicity | | | | |
| Acute Aquatic Toxicity¹ | <ul style="list-style-type: none"> • $LC_{50}/EC_{50}/IC_{50} <1$ mg/l; or • GHS Category 1 | <ul style="list-style-type: none"> • $LC_{50}/EC_{50}/IC_{50}$ 1-100 mg/l; or • GHS Category 2 or 3 | <ul style="list-style-type: none"> • $LC_{50}/EC_{50}/IC_{50} >100$ mg/l | |
| Chronic Aquatic Toxicity¹ | <ul style="list-style-type: none"> • NOEC <0.1 mg/l; or • GHS Category 1 | <ul style="list-style-type: none"> • NOEC 0.1-10 mg/l; or • GHS Category 2, 3 or 4 | | <ul style="list-style-type: none"> • NOEC >10 mg/l |
| Human Health | | | | |
| Carcinogenicity* | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • No basis for concern identified or • IARC Group 3 or 4 | |
| Mutagenicity/ Genotoxicity* | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2 | <ul style="list-style-type: none"> • No basis for concern identified | |
| Reproductive toxicity* | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2 | <ul style="list-style-type: none"> • No basis for concern identified | |
| Developmental toxicity* | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity | <ul style="list-style-type: none"> • No basis for concern identified | |
| Endocrine Disruption* | <ul style="list-style-type: none"> • Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans | <ul style="list-style-type: none"> • Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Draft List—Category 1 or 2; or • Japanese list | <ul style="list-style-type: none"> • No basis for concern identified | |

Green Screen Clearly Defined Hazard Thresholds

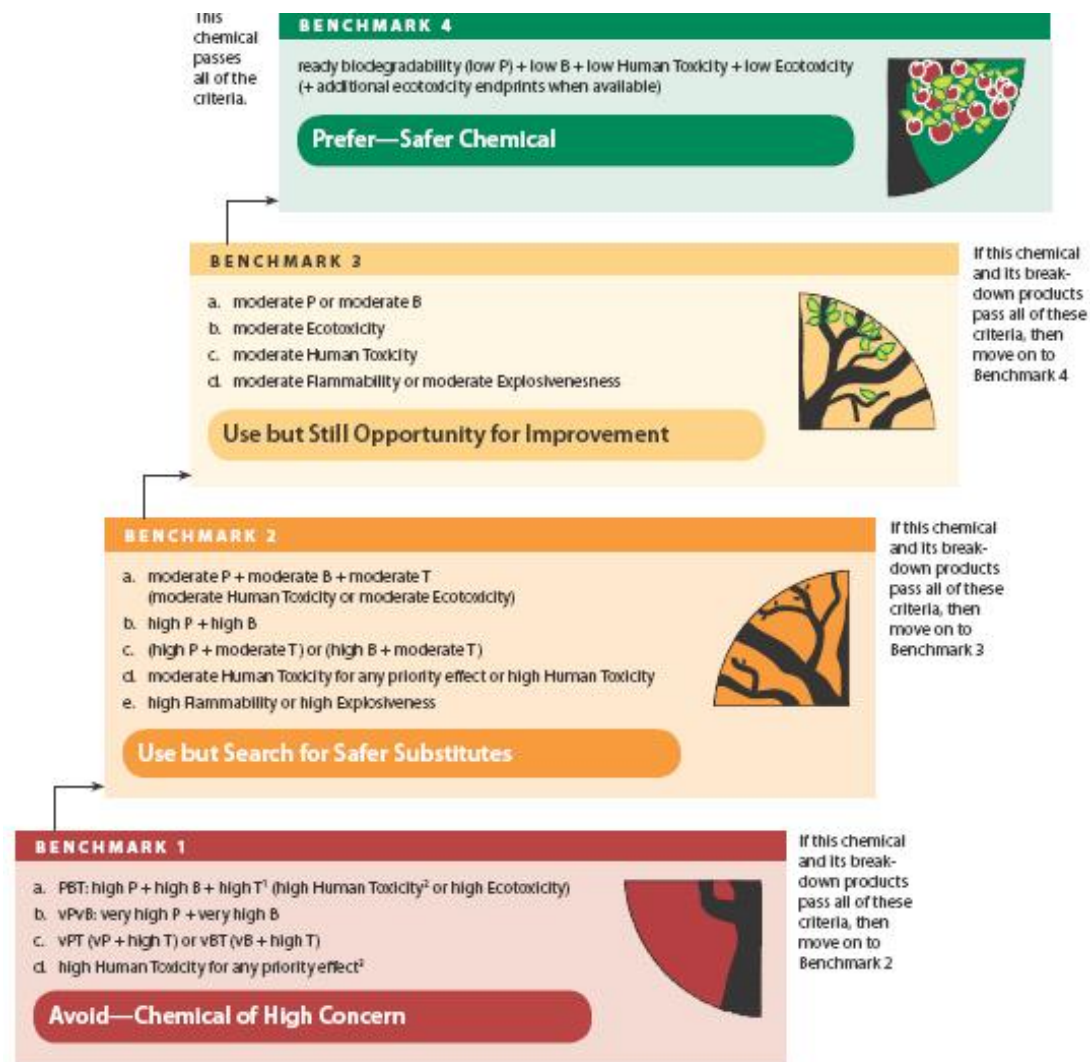
TABLE 3: Threshold Values for Each Chemical Hazard Included in the Green Screen continued

| Hazard | Very High (V) | High (H) | Moderate (M) | Low (L) |
|---|---------------|--|--|---------------------------------|
| Neurotoxicity* | | <ul style="list-style-type: none"> Evidence of adverse effects in humans; or Weight of evidence demonstrates potential for adverse effects in humans | <ul style="list-style-type: none"> Suggestive animal studies; Analog data; or Chemical class known to produce toxicity | No basis for concern identified |
| Acute Toxicity (oral, dermal, or inhalation) | | <ul style="list-style-type: none"> LD₅₀ <50 mg/kg bodyweight (oral); LD₅₀ <200 mg/kg bodyweight (dermal); LC₁₀ <500 ppm (gas); LC₁₀ <2.0 mg/l (vapor); LC₁₀ <0.5 mg/l (dust or mist); US EPA Extremely Hazardous Substance List; or GHS Category 1 or 2 | <ul style="list-style-type: none"> LD₅₀ 50-2000 mg/kg bodyweight (oral); LD₅₀ 200-2000 mg/kg bodyweight (dermal); LC₁₀ 500-5000 ppm (gas); LC₁₀ 2-20 mg/l (vapor); LC₁₀ 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 | | <ul style="list-style-type: none"> 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) | <ul style="list-style-type: none"> 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 | | <ul style="list-style-type: none"> 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 Inocult Patch Tests (HR IPT) (skin) | <ul style="list-style-type: none"> Suggestive animal studies; Analog data; or Chemical class known to produce toxicity | No basis for concern identified |
| Immune System Effects | | <ul style="list-style-type: none"> Evidence of adverse effects in humans; or Weight of evidence demonstrates potential for adverse effects in humans | <ul style="list-style-type: none"> 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) | | <ul style="list-style-type: none"> 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 | <ul style="list-style-type: none"> 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 | | <ul style="list-style-type: none"> GHS Category: Unstable explosives or DMsions 1.1, 1.2, or 1.3 | <ul style="list-style-type: none"> GHS Category: Divisions 1.4 or 1.5 | No basis for concern identified |
| Flammable | | <ul style="list-style-type: none"> GHS Category 1—Flammable Gases; GHS Category 1—Flammable Aerosols; or GHS Category 1 or 2—Flammable Liquids | <ul style="list-style-type: none"> 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
Clearly Defined
Hazard Thresholds,
cont'd.

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



FOOTNOTES:

- 1 Toxicity – "T" = human toxicity and ecotoxicity
- 2 Human Toxicity = priority effects (see below) or acute toxicity, immune system or organ effects, sensitization, skin corrosion, or eye damage
- 3 Priority Effects = carcinogenicity, mutagenicity, reproductive or

ABBREVIATIONS:

- B = bioaccumulation P=persistence
T=human toxicity and ecotoxicity
vB=very bioaccumulative vP=very persistent

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 | <p>Breakdown products stop decaBDE at Benchmark 1:</p> <ul style="list-style-type: none"> • 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 | <p>Breakdown product and formulation contaminant, bisphenol A, is of high concern for endocrine disruption—stopping BPADP at Benchmark 1(d)</p> | Benchmark 1: Avoid—Chemical of High Concern |
| RDP and its breakdown products | 125997-21-9 | <ul style="list-style-type: none"> • 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

- Supports concurrent strategies for greening chemical inventories
- Supports Business NGO Forum Chemical Policy Principles
- Builds on USEPA Design for the Environment hazard assessment protocols
 - **Considers significant transformation products**
 - **Expands hazard considerations (endocrine disruptors; flammability, explosiveness)**
- Focuses on comparative hazard assessment (not risk)
- Defines green chemicals
- Scientifically rigorous
- Open, transparent and publicly available
- Drives continual improvement and innovation



The Green Screen Method: v2.0

- Chemical Policy Principles
 - Align with Chemical Policy Principles Implementation Guide
- Pursuing partnership efforts
 - Case studies (e.g., polymer additives)
 - Increasing public availability
- Version 2 modifications to facilitate ease of use
 - Supporting lists to define chemicals of concern
 - Alignment with DFE General Screen
 - Expansion to include some inorganics (i.e., mineral FRs)
 - Decision strategies for limited data sets



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

END

Applying the Green Screen to FRs in PCBs

| Green Screen - "CONFIDENTIAL, INCOMPLETE & DRAFT ONLY" Assessment of Alternatives to TBBPA | | | | | |
|--|------------|--------------------|--|--|--------------------|
| Chemical | CAS # | Benchmark Achieved | Reasons for Benchmark | Persistence | BCF |
| Reactive Chemicals | | | | | |
| TBBPA + its reaction and combustion byproducts | | | | | |
| TBBPA | 79-94-7 | Benchmark 2 | Moderate: developmental; High acute aquatic toxicity; High chronic aquatic toxicity; High: persistence [using Green Screen criteria, moderate if using EPA criteria] | H Aerobic biodegradation - not readily biodegradable; soil & sediment: >60d + <180d Aerobic biodegradation - water: primary = weeks-months; ultimate = recalcitrant Air: 3.6d | L <500 measured |
| TBBPA Reaction Product (DER 538) | 26265-08-7 | Benchmark 2 | Moderate: cancer, reproductive, developmental, genotoxicity, skin sensitization High: persistence [using Green Screen criteria, moderate if using EPA criteria] | Aerobic biodegradation - soil & sediment: >60d; ultimate = >60d Aerobic biodegradation - water: primary = >60d; ultimate = >60d Air: <2d | L <500 |
| TBBPA degradation products and metabolites | | Benchmark 1 | Anaerobic biodegradation in soil yielded complete dehalogenation to BPA in 45 days and the BPA was not degraded after 3 months. Pyrolysis at 700-900C yielded mono, di-, tri- and tetra- PBDD and PBDF | | |

Combustion products

TO BE DETERMINED

| | | | | | |
|--|-------------|-------------|---|---|------|
| DOPO + its reaction and combustion byproducts | | | | | |
| DOPO | 35948-25-5 | Benchmark 3 | Moderate: aquatic toxicity - acute and chronic | H Aerobic biodegradation - soil & sediment: >60d + <180d Aerobic biodegradation - water: primary + ultimate = <60d Air: 1.8d | <500 |
| DOPO Reaction Product (Dow XZ-92547) | proprietary | Benchmark 2 | Moderate: cancer, reproductive, developmental, genotoxicity very High: persistence | Expected to be recalcitrant to biodegradation | <100 |
| Degradation Products and Metabolites | | | NA | | |
| Combustion products | | | TO BE DETERMINED | | |

Fyrolflex (aryl alkylphosphonate) + its reaction and combustion byproducts

| | | | | | |
|--------------------------------------|-------------|-------------|---|---|------|
| Fyrolflex PMP | proprietary | Benchmark 3 | very High: persistence | vH Expected to be recalcitrant to biodegradation | <100 |
| Fyrolflex Reaction Product | unknown | Benchmark 2 | Moderate: cancer, reproductive, developmental, genotoxicity very High: persistence | | |
| Degradation Products and Metabolites | | | NA | | |
| Combustion products | | | TO BE DETERMINED | | |

Additive Flame Retardants

Exolit OP930 (phosphoric acid, diethyl-,aluminum salt) + its reaction and combustion byproducts

| | | | | | | |
|--------------------------------------|-------------|-------------|---|---|---|-------|
| Exolit OP 930 | 225789-38-8 | Benchmark 2 | Moderate: developmental, neurological very High: persistence | H | Organic counter ion: ultimate aerobic water biodegradation = <60 Metal ion: recalcitrant to biodegradation | <1000 |
| Degradation Products and Metabolites | | | | | | |
| Combustion products | | | TO BE DETERMINED | | | |

Melapur 200 + its reaction and combustion byproducts

| | | | | | | |
|--------------------------------------|-------------|-------------|--|--|---|---------|
| Melapur 200 | 218768-84-4 | Benchmark 2 | Moderate: genotoxicity High: persistence <i>[using Green Screen criteria, moderate if using EPA criteria]</i> | | Persistence based on melamine data | <1000 |
| Polyphosphoric acid | 8017-16-1 | Benchmark 4 | Low: all endpoints | | weight of evidence: it will hydrolyze under environmental conditions | no data |
| Melamine | 108-78-1 | Benchmark 2 | Moderate: genotoxicity High: persistence <i>[using Green Screen criteria, moderate if using EPA criteria]</i> | | Aerobic biodegradation - water: primary = days-weeks; ultimate = weeks-months | no data |
| Degradation Products and Metabolites | | | | | | |
| Combustion products | | | TO BE DETERMINED | | | |

Fillers

Aluminum Hydroxide + its reaction and combustion byproducts

| | | | | | | |
|--------------------------------------|------------|-------------|--|--|--|------|
| Aluminum hydroxide | 21645-51-2 | Benchmark 2 | Moderate: neurological very High: persistence | | Inorganic material, it is not expected to biodegrade | <500 |
| Degradation Products and Metabolites | | | NA | | | |
| Combustion products | | | Combustion: aluminum hydroxide degrades to alumina during smelting | | | |

Silicon Dioxide (amorphous; includes particles < 10µ) + its reaction and combustion byproducts

| | | | | | | |
|--------------------------------------|-----------|-------------|--|--|---|------|
| Silicon dioxide amorphous | 7631-86-9 | Benchmark 2 | High: systemic very High: persistence | | Persistent: inorganic materials | <500 |
| Degradation Products and Metabolites | | NA | NA | | Silicon dioxide is inert under typical environmental conditions | |
| Combustion products | | | TO BE DETERMINED | | | |

Silicon Dioxide (crystalline; includes particles < 10µ) + its reaction and combustion byproducts

| | | | | | | |
|--------------------------------------|-----------|-------------|---|--|---|--|
| Silicon dioxide crystalline | 1317-95-9 | Benchmark 1 | crystalline silica at <10 micron particle size is carcinogenic by inhalation and persistent | | Persistent: inorganic materials | |
| Degradation Products and Metabolites | | NA | NA | | Silicon dioxide is inert under typical environmental conditions | |
| Combustion products | | | TO BE DETERMINED | | | |



Think of it as a way for a manufacturer of chemical intensive products to improve his/her golf game...and lower their handicap.

Benchmark 4

Prefer – Safer Chemical



Benchmark 3

Use but Still Opportunity for Improvement



Benchmark 2

Use but Search for Safer Substitutes



Benchmark 1

Avoid – Chemical of High Concern



You really want to blast your way out of this hazard! – and get back on course