The Green Screen for Safer Chemicals Version 1.0

A growing number of companies are engaging in sustainability initiatives that include corporate social responsibility and environmental stewardship. One of the most compelling areas of potential innovation for sustainability is green chemistry. Green Chemistry is "the utilization of a set of principles that reduces the use and/or generation of hazardous substances in the design, manufacture and application of chemical products."[1] The 12 Principles of Green Chemistry[1] call for the design of chemicals that are fully effective and inherently safer—such chemicals will have little or no toxicity; use innocuous or better yet, avoid the need for solvents and auxiliaries in manufacturing; break down to innocuous substances that do not accumulate in the environment; and minimize the potential for chemical accidents including explosions, fires and releases to the environment.

In practice, chemists can use the 12 Principles to guide their practices. However, for most companies, product design and development and even operation and maintenance activities involve the *selection* of chemicals and materials rather than the creation of new molecules. These companies are chemical and material "choosers" who depend on suppliers for providing raw material options. Their challenge is to identify greener chemicals and materials for use in their products and processes. A significant challenge to greening one's chemical inventory is the absence of a method to determine whether a chemical is in fact "greener". We have found that many organizations will not take action to green their chemical inventories if they do not see agreement on what constitutes a green (or greener) chemical. Based on this need, the Green Screen for Safer Chemicals was developed as the first open source method to rank chemicals according to a process of comparative hazard assessment. The Green Screen is a benchmarking tool that assesses a chemical's hazard with the intent to guide decision making toward the use of the least hazardous options via a process of informed substitution. Informed substitution, a term coined at the US EPA, is the considered transition from a chemical of particular concern to a safer chemical or non-chemical alternative. Informed substitution builds on the best available information and leads to cleaner production and the development or use of less hazardous chemical and non-chemical technologies. It also minimizes the opportunity for unintended consequences. Informed substitution is a principle that underlies effective alternatives assessment.

The Green Screen is a benchmarking tool that assesses a chemical's hazard with the intent to guide decision making toward the use of the least hazardous options via a process of informed substitution.

Setting the Foundation of the Green Screen

At the foundation of the Green Screen method are the principles of Green Chemistry and the work of the US Environmental Protection Agency's (EPA's) Design for Environment (DfE) program.

The Green Screen addresses many of the principles of green chemistry through its focus on hazard reduction. A basic premise behind green chemistry and the Green Screen is that chemical risk is most effectively managed by reducing hazard, rather than controlling exposure. Risk management typically attempts to reduce risk by controlling exposure. Yet, exposure controls can and do fail, and products are used in ways that were never intended. Therefore the most effective means to reduce risk is to reduce hazard. The primacy of hazard reduction as the preferred option for reducing risk is established in the Pollution Prevention Act of 1990, which defines pollution prevention (also known as source reduction) as any practice that "reduces the hazards to public health and the environment."[2]

The structure of Green Screen method builds from the chemical assessment approach developed by the US EPA's DfE Program, especially, the partnerships on Furniture Flame Retardancy[3] and Flame Retardants in Printed Circuit Board.[4] For these partnerships the DfE Program integrated knowledge from the US EPA's

New Chemicals Program—which assesses the potential risks of new chemicals that manufacturers propose to bring to market[5]—into hazard assessments of chemical flame retardants. The chemical flame retardant assessments evaluate each chemical in a formulated product for

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11 hazard endpoints (including carcinogenicity, reproductive toxicity, ecotoxicity, persistence, and bioaccumulation) and assign a level of concern of high, moderate or low (for each endpoint for each chemical). The result is a comprehensive hazard assessment presented in an easy to read matrix (see Table 4-1 in *Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam*).[6]

The DfE method provides a comparative hazard assessment across a comprehensive set of hazard endpoints. Hazard assessment is a key component of risk assessment. It is also needed for alternatives assessment. The power of the comparative hazard assessment approach, particularly when comparing chemicals with similar functional use (ie as flame retardants in polyurethane foam) is that it allows one to compare and select safer alternatives. Risk assessment typically answers the question, Is a chemical safe, or safe enough for a particular use. Alternatives assessment on the other hand asks which is safer? A question that aligns well with a strategy of continual improvement. As more and more companies are faced with the need to phase out chemicals of high concern used in their industry—whether prompted by regulations or internal initiatives—they need to look for safer alternatives. The challenge for them becomes how to determine that the alternatives are indeed safer.

The DfE approach is helpful in laying out chemicals hazard information in a clear and comprehensive format. However, it intentionally does not indicate which alternatives are preferable. A need for guidance on how to evaluate chemical hazard information to support decision making is needed and prompted in part the development of the Green Screen—a comparative hazard assessment method that defines a path to selecting chemicals that are inherently safer for humans and the environment.

Building the Green Screen Method

The Green Screen defines four benchmarks on the path to safer chemicals, with each benchmark defining a progressively safer chemical:

- **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"

Each benchmark depicted in Figure 1 (page 3) includes a set of hazard criteria that a chemical, along with its known and predicted breakdown products and metabolites, must pass. Including the known and predicted degradates of a chemical into the Green Screen is important: it addresses the potential impacts of a chemical once released into the environment. A precedent for including degradation products into a chemical assessment is the US EPA DfE assessment of alternatives to penta-bromodiphenyl ether (pentaBDE) in furniture foam, where the Agency noted the likelihood of persistent degradation products for each chemical alternative.[6]

To progress from Benchmark 1 to Benchmark 2, a chemical (and its breakdown products and metabolites) must pass all the criteria specified under Benchmark 1. For example, a chemical (along with its breakdown products and metabolites) that is persistent, bioaccumulative and toxic (PBT) would not pass beyond Benchmark 1. To progress from Benchmark 2 to Benchmark 3 and from Benchmark 3 to Benchmark 4, the chemical (along with its breakdown products and metabolites) must pass all criteria specified under each respective benchmark. The criteria become increasingly more demanding for environmental and human health and safety for each benchmark, with the hazard criteria of Benchmark 4 representing the safest chemical.

The development of the Green Screen method involved three major steps:

1. **Establish the list of hazard endpoints** critical to evaluating the safety of a chemical.
2. **Define the levels of concern**—high, moderate, and low—for each hazard endpoint.
3. **Specify the hazard criteria** for each of the four benchmarks.

Specifying Hazard Endpoints

The Green Screen list of hazard endpoints tracks the hazards government agencies are incorporating into their chemical assessments, including the: US EPA, Environment Canada, International Joint Commission (a commission established by the US and Canada to protect transboundary waters),

FIGURE 1

Green Screen for Safer Chemicals v 1.0

Start at Benchmark 1 (red) and progress to Benchmark 4 (green)

This chemical passes all of the criteria.

BENCHMARK 4

ready biodegradability (low P) + low B + low Human Toxicity + low Ecotoxicity (+ additional ecotoxicity endprints when available)

Prefer—Safer Chemical

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 4

BENCHMARK 3

a. moderate P or moderate B
b. moderate Ecotoxicity
c. moderate Human Toxicity
d. moderate Flammability or moderate Explosivenesness

Use but Still Opportunity for Improvement

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 3

BENCHMARK 2

a. moderate P + moderate B + moderate T (moderate Human Toxicity or moderate Ecotoxicity)
b. high P + high B
c. (high P + moderate T) or (high B + moderate T)
d. moderate Human Toxicity for any priority effect or high Human Toxicity
e. high Flammability or high Explosiveness

Use but Search for Safer Substitutes

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 2

BENCHMARK 1

a. PBT: high P + high B + high T (high Human Toxicity or high Ecotoxicity)
b. vPvB: very high P + very high B
c. vPT (vP + high T) or vBT (vB + high T)
d. high Human Toxicity for any priority effect

Avoid—Chemical of High Concern

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 developmental toxicity, endocrine disruption, or neurotoxicity

ABBREVIATIONS:

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

the European Union's recently enacted chemicals policy legislation (Registration, Evaluation and Authorization of Chemicals–REACH), and the Stockholm Convention on Persistent Organic Pollutants (an international treaty signed in 2001 and convened by the United Nations Environment Programme).

In the Green Screen the hazards of a chemical are defined by its potential to cause acute or chronic adverse effects in humans or wildlife, its fate in the environment, and certain physical/chemical properties of concern to human health. Acute mammalian toxicity (lethality) and irritation of the skin or eye are examples of acute adverse effects that can result from inhalation, ingestion, or dermal contact with a chemical. Chronic effects occur after repeated exposures and include cancer and adverse effects to the reproductive, neurological, endocrine, or immune systems. The fate of a chemical in the environment—"environmental fate"—is strongly determined by its rate of degradation (defined as persistence) and its tendency to accumulate in tissues and organs (bioaccumulation). The physical/chemical properties of concern in the Green Screen are flammability and explodability.

The Green Screen list of hazards shown in Table 1 closely tracks the hazards incorporated into the US EPA DfE Program's summary assessment of alternatives to the brominated flame retardant, pentaBDE. The most notable difference among endpoints is the inclusion of endocrine disruption as a hazard endpoint in the Green Screen (but not the DfE program's assessment),

While endocrine disruption is not considered an adverse effect per se—"but rather a potential mechanism of action,"[7] particularly for developing organisms—changes in hormone levels and/or disruption of hormonally regulated processes, such as those caused by endocrine disrupting chemicals can lead to severe health effects. And there is precedent for using endocrine disruption in assessing the risks posed by a chemical. For example, in the US EPA's revised draft risk assessment for dibutyl phthalate (DBP), the Agency proposes to use changes in hormonal levels caused by DBP (which is an anti-androgen—it blocks or interferes with action of male sex hormones) to set the reference dose (RfD) for DBP. Specifically, the US EPA has identified reduction in fetal testosterone as the critical effect for the regulation of DBP. Despite the reduction being reversible, the Agency concluded that it can cause irreversible effects if it occurs during a critical window of development.[8] Because chemicals that are endocrine disruptors pose serious risks to the health of humans or wildlife, endocrine disruption is included among the Green Screen list of hazards.

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Note that the European Union's REACH legislation includes endocrine disrupting properties among the list of hazards to be used when identifying chemicals of very high concern.[9]

The Green Screen establishes a set of priority human health effects based on concern for chemical effects that can be triggered at low doses, have the potential to cause irreversible effects, are difficult to manage through conventional control measures, or are included as priorities in existing government chemical assessment programs. The priority effects are: carcinogenicity, mutagencity/genotoxicity, developmental toxicity, reproductive toxicity, endocrine disruption, and neurotoxicity. Being a "priority effect" in the Green Screen means more stringent treatment in the benchmarks.

Defining Levels of Concern for Each Hazard Endpoint

Each hazard in the Green Screen is divided into three levels of concern: high, moderate, and low. Two hazards, persistence and bioaccumulation, have an additional level of concern of very high, which reflects the growing international consensus in defining very persistent and very bioaccumulative (vPvB) chemicals. Each level of concern (for each hazard) is defined by threshold values that are quantitative, qualitative, or based on expert references. Table 1 (pages 5 and 6) lists the threshold values used in the Green Screen for each hazard endpoint.

The threshold values developed for the Green Screen rely primarily on the US EPA's DfE program and the Globally Harmonized System for the Classification and Labeling of Chemicals (or "GHS" for short). The GHS hazard categories are defined from most to least hazardous characteristics.[10]

The most significant differences between the threshold values in the Green Screen and the US EPA's DfE chemical assessments are the levels of concern for P and B. As Table 2 reveals, there is wide variation in setting threshold values for high persistence and high bioaccumulation potential, even within the US EPA. For example, as shown in Table 2 (page 8), the high level of concern for B used by the US EPA DfE program of a bioconcentration factor (BCF) > 5000 is the very high level of concern used by the European Union (EU) and Stockholm Convention on Persistent Organic Pollutants (POPs), and much greater than the level at which a chemical is considered bioaccumulative by the Federal Register Final Rule on

TABLE 1 **Threshold Values for Each Chemical Hazard Included in the Green Screen v 1.0[1]**

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, sediment >60 to 180 days; · Water >40 to 60 days; or · Potential for long-range environmental transport	· Soil, sediment 30 to 60 days; or · Water 7 to 40 days	· Soil, sediment <30 days; · Water <7 days; or · Ready bio-degradability
Bioaccumul-ation 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; · 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; · 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 o r 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 that mechanisms of action lead to adverse effects	· 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

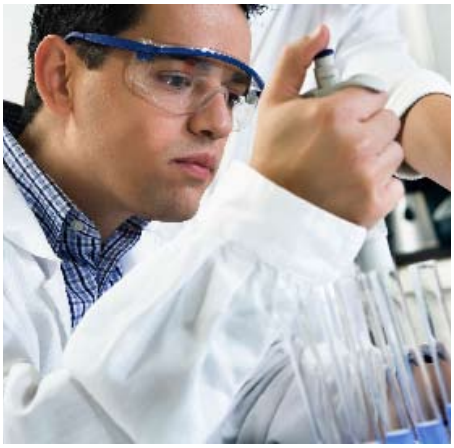
TABLE 1 **Threshold Values for Each Chemical Hazard Included in the Green Screen v 1.0[1]** (continued)

Hazard	Very High (v)	High (H)	Moderate (M)	Low (L)
Human Health (continued)				
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, 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

1 * = Priority Human Health Effect. [1] = Experimental data are preferred. Absent experimental data, values based on structure activity relationships are sufficient.

Abbreviations: BAF=bioaccumulation factor; **BCF**=bioconcentration factor; **EC_{50}=**median effective concentration; **EU**= European Union; **GHS**=Globally Harmonized System of Classification and Labelling of Chemicals; **IARC**=International Agency for Research on Cancer; **IC_{50}=**mean inhibitory concentration; **LC_{50}=**median lethal concentration: the concentration at which 50% of test animals died after exposure; **LD_{50}**=median lethal dose: the dose at which 50% of test animals died during exposure; **log Kow**=log-octanol water partition coefficient; **NOEC**=no observed effect concentration; **NTP**=National Toxicology Program; **OSHA**=Occupation Safety and Health Administration

PBTs, which sets a BCF level of > 1000. Similarly P levels of greater than 60 days for water have been sufficient to rate a chemical as highly persistent by the EU, Washington State, the Final Rule on PBTs, but not the DfE Program, which uses >180 days in water. The threshold values in the Green Screen for persistence and bioaccumulation are set to be highly protective of human health and the environment.



Chemical manufacturers have not been required to generate comprehensive test data before providing EPA with pre-manufacturing notification about a new chemical intended for commercial use. As a result, the vast majority of the more than 80,000 chemicals on the market have limited to no publicly available test data.

Another type of threshold value used in the Green Screen is a reference to chemical lists developed by organizations with expertise in that area. The expert reference lists included in the Green Screen are: International Agency for Research on Cancer (IARC—carcinogenicity),[11] Occupational Safety and Health Administration (carcinogenicity),[(12)] National Toxicology Program (carcinogenicity and reproductive toxicity),[13,14] California Proposition 65 (carcinogenicity and reproductive/developmental toxicity),[15] European Union (carcinogenicity, mutagenicity, reproductive toxicity, and endocrine disruption),[16,17] Japan (endocrine disruption),[18] and the US EPA (acute toxicity).[19]

Establishing Hazard Criteria for Each Benchmark

The hazard criteria set for each benchmark start from Benchmark 1: Avoid — Chemical of High Concern**.** The Benchmark 1 criteria are consistent with the hazard criteria leading governments are using to restrict the use of a chemical: high or very high P, high or very high B, and/or high toxicity (T). The European Union's new REACH legislation, for example, targets chemicals that are PBTs, vPvBs, or highly toxic to humans (carcinogenic, mutagenic, reproductive toxicant, or endocrine disruptor).[9] Similarly Washington State, Oslo-Paris Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR), and the Stockholm Convention on POPs are targeting chemicals that are PBTs. And Canada is prioritizing chemicals that are not only PBTs, but also P+T or B+T for further assessment.

The four hazard criteria for Benchmark 1 are:

- 1(a) PBT—high P **+** high B **+** high T (high human toxicity or high ecotoxicity); **or**
- 1(b) vPvB—very high P **+** very high B; **or**
- 1(c) vPT (vP **+** high T) **or** vBT (vB **+** high T); **or**
- 1(d) high human toxicity for any priority effect.

Chemicals that persist (are slow to degrade), bioaccumulate in animals (collect in animal tissue or organs) **and** are toxic to humans or animals are especially problematic because their concentrations in the environment increase over time, increasing the opportunities for exerting their toxic effects. The Stockholm Convention on POPs—which is designed to phase-out very persistent, very bioaccumulative and toxic chemicals—reflects the widespread recognition of the risks posed by PBTs (POPs are synonymous with PBTs).

Managing Data Gaps

The most significant challenge to using the Green Screen is the availability of hazard data for a chemical. In the ideal scenario, comprehensive hazard test data as well as complete knowledge of all the metabolites and degradation products would be available for all chemicals. Unfortunately the ideal data scenario is seldom attained because comprehensive hazard data are the exception rather than the norm. To date chemical manufacturers have not been required to generate comprehensive test data before providing EPA with pre-manufacturing notification about a new chemical intended for commercial use,[5] with the outcome that the vast majority of the more than 80,000 chemicals on the market have limited to no publicly available test data.[20] Thus we live in a world of imperfect and incomplete chemical hazard and safety assessment. This creates a challenge to using the Green Screen: how to benchmark chemicals with limited or no experimental test data.

One approach is to supplement test data with analog and structure activity relationship (SAR) analyses to fill as many data gaps as possible. Combining the results of experimental data with the use of modeling tools and expert judgment-based SAR to address hazard endpoints is common practice at the US EPA, Environment Canada, and other government agencies. However, not all endpoints are amenable to modeling and expert judgment, depending in part on the type of molecule and the availability of data on reasonable analogs.

Another approach is to penalize chemicals without comprehensive hazard data (and that cannot be reasonably assessed via modeling or expert judgment) by immediately assigning it to Benchmark 1, until a sufficient data set is generated for that chemical to determine otherwise. The benefit of such an approach would be to encourage manufacturers to generate and submit needed test data.

TABLE 2 **Threshold Values Used by Government Institutions and the Green Screen to Categorize Chemicals as Persistent, Bioaccumulative, and/or Toxic v 1.0**

Hazard	State Criteria	National Criteria—US EPA		Regional Criteria					International	
	Washington State PBT[1]	PBT Chemicals Final Rule[2]	Design for Environment (DfE)[3]	International Joint Commission[4]	OSPAR PBT Definition[5]	European Union (EU) REACH[6]—Substances of Very High Concern			Stockholm Convention on POPs[7]	Green Screen for Safer Chemicals
						vPvB	PBT	Toxicity		
Persistence—P (half-life in days)										
Very High (v)	na	na	na	na	na	>60 water; or >180 soil or sed.	na	na	>60 water; or >180 soil or sed.; + long-range transport	>60 water; or >180 soil or sed.
High (H)	≥60 water, soil, or sed.	>60 water, soil, or sed.; or >2 air	>180 water, soil, or sed.	>56 water	>50 water	na	>60 mw, >40 fw, >180 m sed., or >120 fw sed./soil	na	na	>40-60 water; or >60-180 soil or sed.
Moderate (M)	na	na	60-180 water, soil, or sed.	7-56 water	na	na	na	na	na	7-40 water; or 30-60 soil or sed.
Low (L)	na	na	<60 water, soil, or sed.	<7 water	na	na	na	na	na	<7 water; or <30 soil or sed.
Bioaccumulation—B (bioconcentration factor—BCF; bioaccumulation factor—BAF; or log octanol-water coefficient—log Kow)										
Very High (v)	na	na	na	na	na	BCF >5000	na	na	BCF/BAF >5000 (or log Kow ≥5)	BCF/BAF >5000 (or log Kow>5)
High (H)	BCF/BAF >1000 (or log Kow >5)	BCF/BAF >1000	BCF >5000	BAF >5000	BCF ≥500 (or log Kow ≥4)	na	BCF >2000	na	na	BCF/BAF >1000-5000 (or log Kow >4.5-5)
Moderate (M)	na	na	BCF 1000-5000	BAF 1000-5000	na	na	na	na	na	BCF/BAF 500-1000 (or log Kow 4-4.5)
Low (L)	na	na	BCF <1000	BAF <1000	na	na	na	na	na	BCF/BAF <500 (or log Kow <4)
Toxicity—T (includes: carcinogen-C; developmental-D or reproductive-R toxicant; mutagen-M; neurotoxic-N; or no observed effect concentration-NOEC)										
	Human: C/D/R/N; or RfD <0.003 mg/kg/day. Aquatic: chronic NOEC <0.1 mg/l; acute NOEC <1.0 mg/l	Human: C/M/R/N; other chronic effects; or effects from site releases	Human: chronic effects. Aquatic: chronic/acute toxicity (see EPA 2005 for details)[3]	Aquatic: chronic NOEC: High: <0.1 µg/l; Moderate: 1.0 µg/l	Human: C/M/R; or other chronic. Aquatic: Acute LC/EC_{50} <1 mg/l; chronic NOEC <0.1 mg/l	na	Human: C/M/R; or other chronic toxicity. Aquatic: Chronic NOEC <0.01 mg/l	Human: C/M/R; endocrine disruption; or equivalent concern	Toxicity/ecotoxicity data with potential adverse effects to humans or environment	see Table 3

ABBREVIATIONS:
EC_{50}=median effective concentration; **fw**=freshwater; **LC_{50}**=median lethal concentration; **m**=marine; **mw**=marine water; **na**=not applicable; **OSPAR**=Oslo and Paris Convention for the Protection of the Marine Environment of the Northeast Atlantic; **PBT**=persistent, bioaccumulative, and toxic; **POPs**=persistent organic pollutants; **RfD**=reference dose; **sed.**=sediment; **US EPA**=US Environmental Protection Agency; **vPvB**=very persistent, very bioacumulative.

SOURCES:

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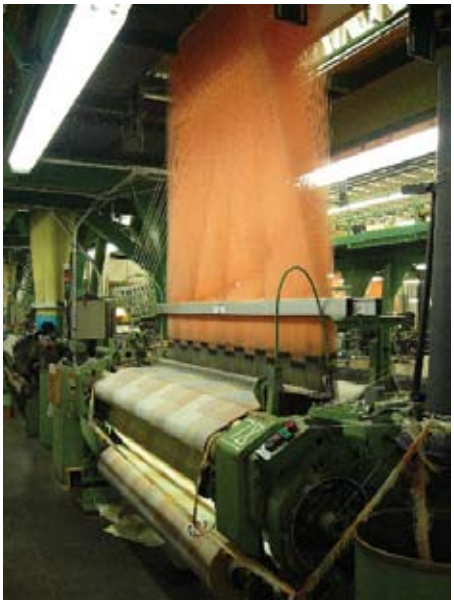
The Green Screen Niche

A handful of proprietary methods have been developed to evaluate and identify safer chemicals and materials and to help define the path to safer, healthier chemicals in product design. Notable examples include the Cradle to Cradle Design Protocol developed by McDonough Braungart Design Chemistry (MBDC),[21] the Greenlist™ developed by SC Johnson and Son, Inc.,[22] and the Dye and Chemistry Protocol developed by Interface Fabrics.[23] None of these methods fully disclose all the decision elements, including: threshold values for hazard criteria, prioritization of hazard endpoints, and life cycle concerns. A transparent and publicly accessible method for categorizing the hazards of chemicals and benchmarking their progress to being safer is needed to support the movement to more sustainable products and green chemicals. The Green Screen specifies the criteria used for categorizing chemicals based on their hazards and makes them available for public review.

The Green Screen complements other chemical assessment programs such as the US EPA DfE's Formulator Program and Partnerships[24] and CleanGredients™, a resource for identifying ingredients for use in environmentally preferable cleaning products. While CleanGredients™ focuses on chemicals that are "best in their functional class," the Green Screen provides a broader metric of hazard assessment—benchmarking chemicals in relation to a definitive set of criteria that do not vary by function. For example, a surfactant that has moderate aquatic toxicity with rapid and complete bio-degradability could be best in its class, but it would not reach Benchmark 4: Prefer—Safer Chemical, of the Green Screen. The Green Screen complements the "best in class" approach and is necessary because one could imagine a scenario where a chemical that is best in its class is still hazardous. For example, some dioxins are more toxic than others, but the least toxic dioxin would not be considered "green."



It is our hope that the application of the Green Screen will lead to the use and generation of inherently safer chemicals, thereby reducing the risks of exposure to toxic chemicals and increasing the availability of safer, healthier products.

Conclusions

The Green Screen is an open source, hazard-based screening method that supports the assessment of greener chemicals for sustainable products. It is designed to inform decision making by businesses, governments, and individuals concerned with the risks posed by chemicals and to advance the development and adoption of greener chemicals. All of the hazard and benchmark criteria developed for the Green Screen are based on government and other precedents for classification. The Green Screen prioritization is consistent with the values unfolding in the REACH Legislation in terms of prioritizing chemicals for authorization or elimination and also with the Canadian Government's categorization scheme.[25]

It is also important to note what the Green Screen is not. It is not intended to address all of the critical elements of sustainability. It is just one useful tool in the toolbox. For example, it does not consider social equity or important life cycle impacts such as energy quantity and quality. Nor does it consider all life cycle impacts, for example, the reagents used to synthesize a chemical are not part of the Green Screen. Rather it focuses on comparative hazard assessment of chemicals and chemical products from their point of generation, on. However, the Green Screen can be applied to chemicals used or generated at any life cycle stage.

The Green Screen, Version 1.0 will continue to evolve based on user and reader feedback. Version 2.0 will refine some of the threshold definitions to better align with standard test methods. In addition, it will be expanded to address certain classes of inorganics such as mineral oxides to allow for comparison of inorganic chemicals used as flame retardants. It is our hope that its application will lead to the use and generation of inherently safer chemicals, thereby reducing the risks of exposure to toxic chemicals and increasing the availability of safer, healthier products.

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