

**The GreenScreen™ for Safer Chemicals v 1.2
Guidance for Hazard Assessment and Benchmarking Chemicals**

Contents

I. General Guidance

- 1. Keeping GreenScreen™ Assessments Up to Date**
- 2. Steps to Assess and Classify Hazards**
- 3. Grouping of Endpoints**
- 4. Assessing Mixtures**

II. Hazard Assessment Guidance

- 1. *De minimus* Rule**
- 2. Identifying transformation products to assess**
- 3. Assessing hazards for inorganic chemicals**
- 4. Assessing hazards for polymers**
- 5. Use of secondary literature**
- 6. Prioritizing hazard information for hazard classification**

III. Benchmarking Guidance

- 1. Benchmarking Chemicals with Data Gaps (DGs)**
- 2. Impact of Transformation Products on Benchmarking**
- 3. Benchmarking Inorganic Chemicals**

IV. Reporting Guidance

- 1. Reporting Guidance for the *de minimus***
- 2. Reporting Requirements for the Hazard Assessment**
- 3. Reporting Requirements for the Hazard Summary Table**
- 4. Reporting Requirements for a Benchmark Score**

I. General Guidance

1. *Keeping GreenScreen™ Assessments Up-to-Date*

GreenScreen™ scores are dynamic for several reasons. Regulatory requirements and toxicology continue to evolve rapidly. Therefore new hazard classifications, new test data and new science continue to emerge. In addition, the GreenScreen™ will be regularly revised and updated, particularly as new versions of important foundational pieces such as the Globally Harmonized System of Classification and Labeling are released. In order to assure clarity about versions and the extent to which assessments are current:

- a. The version of the GreenScreen™ used for an assessment should always be identified in the assessment along with the date. Results should not be directly compared between versions. The older assessment should be revised to meet the criteria of the newer version in order to compare assessments.
- b. GreenScreen™ assessments should be revised at a minimum of every three years. It is recommended that chemicals re-assessed annually to ensure that the hazard profiles remain up to date.

2. *Steps to Assess and Classify Hazards*

1. Identify the parent chemical along with relevant analogs (surrogates) and moieties.
2. Screen against all GreenScreen™ Specified Lists¹.
 - a. Identify chemicals on Authoritative A lists and classify hazard level.
 - b. Identify chemicals on Authoritative B and Screening A and B lists.
 - c. Perform additional research to assign hazard levels to all chemicals found on Authoritative B and Screening A and B lists.
3. Conduct a comprehensive toxicological literature search and hazard assessment with particular focus on hazard endpoints not classified in Step 2 above.
4. Where data gaps for hazard endpoints remain, use analogs, models and expert judgment to assess those endpoints.
5. Assign a data gap (DG) classification to any hazard endpoints where there is insufficient information to assess the hazard.

3. *Grouping of Endpoints*

The GreenScreen™ hazard endpoints are divided into the following groups:

- Group I Human Health
 - Carcinogenicity (C)
 - Mutagenicity/Genotoxicity (M)
 - Reproductive Toxicity (R)
 - Developmental Toxicity incl. Neurodevelopmental Toxicity (D)
 - Endocrine Activity (E)
- Group II and II* Human Health
 - Group II
 - Acute Mammalian Toxicity (AT)
 - Systemic Toxicity/Organ Effects– Single Exposure sub-endpoint (ST-single)
 - Neurotoxicity – Single Exposure sub-endpoint (N-single)
 - Irritation/Corrosivity – Eyes (IrE)
 - Irritation/Corrosivity – Skin (IrS)
 - Group II*
 - Systemic Toxicity/Organ Effects – Repeated Exposure sub-endpoint (ST-repeated)
 - Neurotoxicity – Repeated Exposure sub-endpoint (N-repeated)
 - Respiratory Sensitization (SnR))
 - Skin Sensitization (SnS)
- Ecotoxicity
 - Acute Aquatic Toxicity (AA)
 - Chronic Aquatic Toxicity (CA)
- Fate
 - Persistence (P)
 - Bioaccumulation (B)
- Physical/Chemical Properties

¹ GreenScreen™ Specified Lists are identified in the GreenScreen™ Hazard Criteria and GreenScreen™ Specified Lists and Information Sources.

- Flammability (F)
- Reactivity (Rx)

Group I Human Health endpoints include Carcinogenicity, Mutagenicity/Genotoxicity, Reproductive Toxicity, Developmental Toxicity (including Neurodevelopmental Toxicity) and Endocrine Activity. These endpoints reflect priorities that are consistent with priorities reflected in national and international governmental regulations. These endpoints cover hazards that can lead to chronic or life-threatening effects or adverse impacts that are potentially induced at low doses and transferred between generations.

Group II and II* Human Health endpoints reflect hazards that are also important for understanding and classifying chemicals. Group II and II* are differentiated in the Benchmarking system because Group II endpoints have 4 hazard levels (vH, H, M and L) while Group II* endpoints have 3 hazard levels (H, M and L).

Systemic Toxicity/Organ Effects and Neurotoxicity endpoints can belong in either Group II or Group II* depending on whether the data are generated from single exposure (acute) or repeated exposure (sub-chronic or chronic) studies. Results from single and repeated exposures are not considered as separate endpoints but rather sub-endpoints. If data exist for both single and repeated exposure studies, and if both are of good quality, then data from repeated exposure studies should be used.

4. Assessing Mixtures

When assessing mixtures, all chemicals in the mixture should be evaluated independently using the GreenScreen™. The GreenScreen™ method does not include weighted scoring approaches. Instead, for Benchmarking mixtures, the following scoring strategy should be used:

- a. Report the lowest scoring constituent of the mixture.
- b. Report the percent (specify weight, mass or volume) of constituents that achieve each Benchmark level (i.e., , 10% of the formulation by volume achieves Benchmark 2 (BM2) and 90% of the formulation achieves Benchmark 3 (BM3).

II. Hazard Assessment Guidance

1. De minimus Rule

It is recommended that every chemical intentionally added to the material, formulation, or article by the manufacturer be assessed. It is also recommended that every chemical present in a material , formulation, or article at greater than or equal to 100 ppm (0.01%) be assessed.

An intentionally added chemical in a product means a chemical in a product that serves an intended function in the product component². Any other chemical in the product is therefore an impurity.

² <http://www.ecy.wa.gov/pubs/wac173334.pdf>

On a case-by-case basis, unintentionally added chemicals below 100 ppm (0.01%) may be evaluated if they could potentially present a higher than acceptable risk at low levels. These chemicals are typically identified based on life cycle knowledge, particularly of upstream manufacturing processes³.

Where a *de minimus* value of 100ppm (0.01%) is not feasible or practicable, a *de minimus* value of 1000 ppm (0.1%) may be used.

2. *Identifying Transformation Products to Assess*

Expert judgment is required in identifying **feasible** and **relevant** transformation products for inclusion in the assessment of a chemical. This can be difficult. The intention is to identify the few chemicals that are both generated through feasible transformation processes and that are relevant because of their hazard profiles. Transformation products are considered relevant if they can reasonably be expected to be formed, and if there is a real potential for human or environmental exposure.

Chemicals that are particularly hazardous, persistent and/or potentially bioaccumulating and/or have been detected in bio- or environmental monitoring studies should be given higher priority for assessment. Expert judgment may be applied to determine whether a transformation product is feasible and relevant based on its use and likely end of life scenarios. The intent is to identify transformation products that are potentially of concern due to their expected presence, their hazard profiles, and whether or not there are any exposure scenarios to be considered.

Consider the following when identifying feasible and relevant transformation products:

1. Any feasible transformation pathway may generate transformation products. Feasible transformation pathways include biodegradation, hydrolysis, photolysis, oxidation, combustion, etc.
2. Transformation products should be considered if they are feasible based on:
 - a. The use of the parent chemical in a product (e.g. a product is exposed to the air when used, so oxidation is feasible).
 - b. The product's end-of-life management patterns (e.g. the product is typically disposed of down the drain, so therefore aquatic biodegradation is a feasible break-down mechanism).
3. Transformation products with potential for extended exposure should be considered. A transformation product is not considered relevant if it is determined by expert judgment to be either very transient or unlikely to occur. For example, a chemical that is a transient intermediate during biodegradation may not be relevant.
4. Transformation products that are naturally occurring substances may be considered. However, a naturally occurring transformation product is not considered relevant if it is determined by expert judgment to result in exposure

³ See Reporting Guidance.

less than or equivalent to the normal levels found in the relevant environmental compartment(s).

3. Assessing Hazards for Inorganic Chemicals

The physical properties of chemicals, particularly inorganic chemicals, are relevant to assessing their inherent hazard and toxicity. For example, water solubility can modify the classification of aquatic toxicity, and particle size and shape can determine the potential for a chemical to cause respiratory irritation and/or sensitization. The following steps should be included in the hazard evaluation for inorganic chemicals.

Step 1. Define the following form & physical properties

- Particle size (e.g. silica particles < 10 microns)
- Structure (e.g. amorphous vs. crystalline)
- Mobility (e.g. water solubility, volatility)

Step 2. Identify fate and transformation products for inorganic chemicals. Inorganic chemicals have additional consideration beyond those of organic chemicals.

- Parent
- Dissociation products and moieties⁴
- Transformation products
- Valence states

Step 3. Classify hazards for the inorganic chemical and moieties of concern with consideration of physiochemical properties and bioavailability.

4. Assessing Hazards for Polymers

Polymer materials can comprise many constituents. The *de minimus* Rule calls for assessment of all chemicals 1. intentionally added; 2. present at greater than or equal to 100 ppm. Catalysts, residual (unreacted) monomers and processing aids are NOT considered intentionally added but must be assessed if they are present at greater than or equal to 100ppm. In addition, the GreenScreen™ v1.2 Assessment Template calls for the identification and reporting of catalysts, monomers and processing aids and their concentrations in the polymer whether or not the concentration exceeds 100ppm.

5. Use of Secondary Literature

Primary literature sources are preferred. Secondary sources that are considered to be of high quality are acceptable. Examples of high quality secondary sources include government risk assessments and authoritative toxicology databases. If a study is cited from a secondary source, it must be referenced as a secondary source. Publicly available primary data for Flammability and Reactivity may not be available. Secondary sources such as Material Safety Data Sheets may be used for Flammability and Reactivity when there are no other options.

6. Prioritizing hazard information for hazard classification

⁴ Moiety = A discrete chemical entity that is a constituent part or component of a substance.

There are various types of information used for hazard classification including measured and estimated data and hazard lists. The GreenScreen™ includes specified hazard lists defined as follows:

1. Authoritative Lists - Listing is based on a comprehensive expert review by a recognized authoritative body.
2. Screening Lists - Lists are identified as Screening Lists if they were developed using a less comprehensive review; or if they have been compiled by an organization that is not considered to be authoritative; or if they are developed using exclusively estimated data; or if the chemicals are listed because they have been selected for further review and/or testing.
3. A lists - Each category in the list translates directly to a single level of concern for a single GreenScreen™ hazard endpoint, or a single benchmark. The assigned hazard level cannot be modified using additional data.
4. B Lists - Lists that meet one or more of the following: 1) Each category in the list incorporates a single GreenScreen™ hazard endpoint and does not translate directly to a single level of concern or benchmark; AND/OR 2) Each category in the list refers to more than one GreenScreen™ hazard endpoint.

GreenScreen™ carries inherent weightings for types of information. There will be times when conflicting information is found about chemical hazards. In these cases, the information is prioritized as follows:

- Authoritative A lists trump Screening A or B lists. When lists conflict, the most conservative and authoritative results should be used.
- Test data trump estimated values (SAR models, analogs).
- Expert judgment may be applied
- Weight-of-evidence approaches may be applied.

III. Benchmarking Guidance

1. Benchmarking Chemicals with Data Gaps (DGs)

When assessing chemicals, it would be ideal to have access to a complete set of publicly available data covering all hazard endpoints in the GreenScreen™. In reality, most chemicals have insufficient data to assess and classify all of the hazard endpoints. Hazard classifications may be made with test data, authoritative or screening lists, models, estimated values and by using analogs with expert judgment. When there are insufficient data to provide any classification for a hazard endpoint, the endpoint has a data gap (DG).

Data requirements become more stringent with higher Benchmark scores. With solid information on a single endpoint, one can confidently assess a chemical and assign a Benchmark score of 1. Additional data are needed to assess a chemical and confidently assign it a higher Benchmark score.

The number and type of data gaps must be considered when assigning a Benchmark score to a chemical. The following guidance defines the minimum data requirements to achieve a given Benchmark score.

- **Benchmark 1 (BM1):** A chemical may be assigned BM1 with data on as few as one endpoint. For example, if a chemical is definitively classified as a GHS Category 1 (H in GreenScreen™), for the Group I endpoint Carcinogenicity, it would be assigned BM1. A higher score would not be possible. Otherwise, a chemical must meet the minimum data requirements as described for Benchmark 2.

- **Benchmark 2 (BM2):** To achieve BM2, a chemical must have the minimum data set as described below. If a chemical does not achieve the minimum data requirements for BM 2, it will be assigned a “U” (unspecified).
 - a. **Group I Human Health Endpoints:** A chemical must have sufficient data to assess at least 3 out of 5 hazard endpoints (max 2 DGs). Permissible data gaps may only include Endocrine Activity and either Reproductive or Developmental Toxicity. All GreenScreen™ Specified Lists associated with Endocrine Activity must be searched. For Endocrine Activity, a chemical that is not listed and not tested shall be assigned DG.
 - b. **Group II Human Health Endpoints:** A chemical must have sufficient data to assess at least 4 out of 7 endpoints (max 3 DG). Permissible data gaps include the following:
 - i. Skin OR Respiratory Sensitization
 - ii. Skin OR Eye Irritation/Corrosivity
 - iii. One other hazard endpoint (unrestricted)
 - c. **Ecotoxicity Endpoints:** Data are required for at least 1 of 2 endpoints (max 1 DG). Data are required for at least acute or chronic aquatic toxicity.
 - d. **Fate Endpoints:** Data are required for both Bioaccumulation and Persistence (max 0 DG).
 - e. **Physical Property Endpoints:** Data are required for both Flammability and Reactivity (max 0 DG).

However,

 - i. It is sufficient to classify flammability based on data in as few as one relevant sub-category (e.g. flammable liquid).
 - ii. It is sufficient to classify reactivity based on data in as few as one relevant sub-category (e.g. explosivity). If a chemical is not explosive, it meets the requirement for non-reactivity as long as there are no data stating otherwise.

- **Benchmark 3 (BM3):** To achieve BM3, a chemical must have the minimum data set as described below. If a chemical meets the hazard classification requirements of BM3 based on all available data but does not achieve the minimum data requirements for BM3, it will be assigned a downgraded Benchmark Score of 2_{DG}.
 - f. **Group 1 Human Health Endpoints:** A chemical must have sufficient data to assess at least 4 out of 5 hazard endpoints (max 1 DG). The only permissible data gap is for the classification of Endocrine Activity. All hazard lists

associated with Endocrine Activity must be searched. For Endocrine Activity, a chemical that is not listed and not tested shall be assigned DG.

- g. Group 2 Human Health Endpoints: A chemical must have sufficient data to assess at least 5 out of 7 endpoints (max 2 DG). Permissible data gaps include the following:
 - i. Either Skin OR Respiratory Sensitization
 - ii. One other hazard endpoint (unrestricted)
- h. Ecotoxicity Endpoints: Data are required for both Acute and Chronic Aquatic Toxicity endpoints (max 0 DG).
- i. Fate Endpoints: Data are required for both Bioaccumulation Potential and Persistence endpoints (max 0 DG).
- j. Physical Property Endpoints: Data are required both Flammability and Reactivity (max 0 DG).

All available reactivity and flammability data should be assessed. However,

- i. It is sufficient to classify flammability based on data in as few as one relevant sub-category (e.g. flammable liquid).
- ii. It is sufficient to classify reactivity based on data in as few as one relevant sub-category (e.g. explosivity). If a chemical is not explosive, it meets the requirement for non-reactivity as long as there are no data that prove otherwise.

- **Benchmark 4 (BM4):** To achieve BM4, the chemical must have sufficient data to assess all hazard endpoints (max 0 DG). Assessments based entirely on estimated values may not be sufficient to achieve BM4 based on professional judgment⁵. If a chemical meets the hazard classification requirements of BM4 based on all available data but does not achieve the minimum data requirements for BM4, it will be assigned the next lower Benchmark score, which is BM3_{DG}.

2. *Impact of Transformation Products on Benchmarking*

If a feasible and relevant transformation product⁶ is more hazardous than the parent compound, the score of the transformation product may alter the Benchmark score of the parent compound. We recommend you perform a full assessment of all feasible and relevant transformation products. However, for pragmatic reasons, the minimum assessment required for feasible and relevant transformation products is less than a full assessment as described below. See the following rules for benchmarking based on the inherent hazards of a transformation product:

- Benchmark the parent chemical. If the parent compound scores a BM1, then the score of the transformation product does not impact the score of the parent compound.
- If the parent chemical scores BM2, screen all transformation products to determine if any of them would qualify as BM 1 or BM 1 or 2 using the authoritative and screening hazard lists identified in the GreenScreen™ Hazard Criteria table and the GreenScreen™ List Translator.

⁵ In future revisions, there will be a limit to the number of allowable hazard classifications from **estimated** values (placeholder for future requirements).

⁶ See Section 2.b: Identifying transformation products to assess

- If a feasible transformation product is found to be a BM1 chemical, then the parent compound achieves the score of BM1.
- If the transformation products do NOT score BM1 or BM 1 or 2, then the parent chemical retains the original score.
- If a feasible transformation product is found to be a BM1 or 2, then the transformation product should be further assessed to determine if it qualifies as BM1. If further assessment determines that the transformation product is BM1, then the parent compound achieves the score of BM1.
- **BM3:** If the parent compound scores a BM3, then full GreenScreen™ assessments must be performed on all feasible and relevant transformation products. If a transformation product is determined to be BM2, then the score of the parent compound drops one level to BM2.
- **BM4:** If the parent compound scores a BM4, then full GreenScreen assessments must be performed on all feasible and relevant transformation products. If the transformation product is a BM2 or a BM 3, then the benchmark score for the parent compound drops one level to a BM3.

- ***Benchmarking Inorganic Chemicals***

Persistence may be considered a negative characteristic of organic chemicals because it increases the likelihood of exposure. Lack of persistence reflects the likelihood that a chemical will degrade by natural processes in the environment.

For inorganic chemicals, persistence should not necessarily be considered a negative characteristic – particularly for naturally occurring minerals and metal oxides, etc. Attributes including solubility, bioavailability, and particle size are particularly relevant to assessing inorganic compounds.

The benchmark logic in the GreenScreen™ was originally designed for organic chemicals and penalized persistence. In GreenScreen™ v 1.2, a scoring exception is made for inorganic compounds that are highly persistent but have low hazard characteristics with respect to human health and aquatic toxicity. Chemicals that have high persistence where all other hazards are low may achieve BM4.

IV. Reporting Guidance

We recommend using the GreenScreen™ v1.2 Assessment Template. GreenScreen™ is designed to use all available information to screen and compare chemicals. It is important to be transparent in presenting assessment results, clearly communicating both data quality and data completeness. Thus, data gaps must be clearly displayed in the hazard summary table. In some cases, hazard classifications derived from models, analogs and expert judgment can fill data gaps. A visual distinction is made in the hazard summary table between hazard classifications assigned using test data from hazard classifications assigned using estimated values and models.

1. Reporting Requirements for the de minimus

The *de minimus* value used to assess a material, formulation, or article must be reported as part of the assessment.

2. Reporting Requirements for the Hazard Assessment

All information sources must be referenced. See GreenScreen™ v1.2 Assessment Template.

3. Reporting Requirements for the Hazard Summary Table

The fully populated hazard table should include the designated hazard classification level (or designation of DG) for each hazard endpoint box. The following conventions should be used for the Hazard Summary Table:

- Hazard classifications based on test data should use **BOLD** capital letters to depict the hazard classification (e.g. **vH, H, M, L** or **vL**).
- Hazard classifications based on estimated values, models and/or expert judgment should use *ITALIC* capital letters to depict the hazard classification.
- It is helpful to color the background of each hazard endpoint box (vL = deep green; L = light green; M = yellow; H = red and vH = deep red).
- Hazard endpoints with insufficient information to classify the hazard should use “**DG**” to indicate a data gap.
- The hazard classification level for persistence for **inorganic chemicals** may be flagged with a “*” in the hazard table and supplemented with a footnote to emphasize that the chemical is inorganic.

4. Reporting Requirements for the Benchmark Score

The summary results of a GreenScreen™ assessment should include:

- A Benchmark score assigned for the chemical based on the inherent hazards associated with the chemical and consideration of data gaps and transformation products as defined in the guidance.

Where there are data gaps, it is recommended that you include in the results summary a worst-case scenario estimate for a chemical’s BM score by assuming the highest feasible hazard level for those hazard endpoints with DGs (unless expert judgment is deemed sufficiently strong to rule out certain hazards).