

Clean Production Action Commentary on Danish EPA “Environmental and Health Screening Profiles of Phosphorous Flame Retardants” (Environmental Project No. 1823, 2016)”

As part of its work to evaluate alternatives to halogenated flame retardants, the Danish Environmental Protection Agency (EPA) recently released a report providing environmental and health screening profiles for 28 phosphorus flame retardants using GreenScreen® for Safer Chemicals (GreenScreen) as the underlying framework for hazard assessment. GreenScreen is one of three Clean Production Action programs to promote safer alternatives to toxic chemicals in products and supply chains. The stated goals of the Danish EPA project included evaluating GreenScreen’s alignment with principles and criteria in the European Union’s Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and Classification, Labelling and Packaging (CLP) regulations, and the Danish EPA’s requirements for chemical hazard assessment in relation to consumer products. The work was sponsored by the Danish EPA and conducted by the consultancy, COWI A/S.

The Danish EPA and COWI A/S emphasized that GreenScreen is an internationally-oriented hazard assessment approach, leveraging and building upon precedents established under REACH, Globally Harmonized System of Classification and Labelling of Chemicals (GHS), and CLP. The report also highlighted GreenScreen’s alignment with Danish EPA and European Chemicals Agency (ECHA) hazard identification approaches. While the authors concluded GreenScreen is a relevant framework for hazard assessment in Europe, they recommended and implemented what they termed “relatively minor” adaptations to the GreenScreen method as part of the hazard profiling process for the 28 flame retardants included in their study.

Due to the method modifications undertaken in the Danish EPA project, hazard assessment results for the 28 flame retardants published by the Danish EPA are not comparable to existing GreenScreen Benchmark™ scores or Hazard Summary Tables published following the GreenScreen method. As stated in the Danish EPA report, the COWI A/S evaluation of 23 of the 28 flame retardant substances only incorporated data included in prior assessments of these substances conducted by the U.S. Environmental Protection Agency Design for Environmental (US EPA DfE) program.¹

Clean Production Action is issuing this commentary to highlight and clarify the key differences between the Danish EPA hazard profiling approach and the GreenScreen methodology. For detailed information regarding the GreenScreen method, access the [Guidance and Resources](#). For more information on the Danish EPA hazard profiling approach, refer to the agency’s [full report](#).

¹ As part of its work to evaluate safer alternatives to halogenated flame retardants, the U.S. EPA Design for Environment Program completed the following alternatives assessments: [An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether \(DecaBDE\) \(January, 2014\)](#); [Flame Retardants Used in Flexible Polyurethane Foam: An Alternatives Assessment Update \(September 2015\)](#); and [Flame Retardants in Printed Circuit Boards - Final Report \(September 2015\)](#).

Danish EPA Modification of the GreenScreen Method

The Danish EPA project included changes to the GreenScreen Hazard Criteria, Specified Lists, and Benchmark Criteria. Below is a list of key modifications, followed by Clean Production Action's response.

- Within the Danish EPA project, the physical hazard endpoints of reactivity and flammability were excluded, being considered “irrelevant in the consumer product context in the current project”. Unlike GreenScreen Benchmark Criteria, the final scoring criteria used in the Danish EPA report did not include consideration of physical hazards.
- The Danish EPA project employed different hazard criteria to evaluate human health hazards. GreenScreen uses GHS Criteria and Guidance to define hazard criteria for human health endpoints. The Danish EPA project used CLP guidelines instead; the stated reason for the change was to focus on hazard assessment in the European context.²
- The Danish EPA project reviewed a different set of lists than those reviewed for a GreenScreen assessment. A GreenScreen assessment requires review of all GreenScreen Specified Lists. The GreenScreen Specified Lists are lists of chemicals and associated hazards developed by authoritative scientific bodies convened by international, national and state governmental agencies, intergovernmental agencies and NGOs. The information provided by GreenScreen Specified Lists is used to streamline and inform the GreenScreen hazard classification process. Information from “authoritative lists” takes precedence over information from “screening lists”.³ In the Danish EPA project, a number of GreenScreen Specified Lists were not reviewed, including country-specific GHS classifications and lists developed at the U.S. state level. In addition, the Danish EPA project reviewed CLP classifications by industry that are not GreenScreen Specified Lists.
- The Danish EPA study used different criteria than GreenScreen to evaluate endocrine activity. Within GreenScreen, chemicals that are listed by the European Union as Substances of Very High Concern subject to Authorisation (Annex XIV of the REACH Regulation) due to endocrine activity are assigned a high hazard classification, whereas chemicals that are present on the other Specified Lists for endocrine activity are assigned a moderate hazard classification. A review of the scientific literature and weight of evidence approach is used to determine whether a moderate classification based on Specified List information should be elevated to a high hazard. Similarly, if list-

² GreenScreen includes additional hazard categories for acute mammalian toxicity (Category 5), skin irritation (Category 3), and eye irritation (Category 2B) based on GHS Guidance, which are not included in CLP.

³ Authoritative lists are based on a comprehensive expert review by a recognized authoritative body, and result in a classification with a higher level of confidence. Screening lists result in a classification with a lower level of confidence because the list was developed using a less comprehensive review, compiled by an organization that is not considered to be authoritative, developed using predominantly or exclusively estimated data, or developed to identify chemicals for further review and/or testing.

based information is not available, a review of the scientific literature and weight of evidence approach is used to assign a hazard classification. In the Danish EPA study, different criteria were developed to evaluate endocrine activity, based on the EU Priority List criteria and OECD Conceptual Framework for Testing and Assessment of endocrine disrupting chemicals. Two lists included in GreenScreen were not reviewed for the Danish EPA study, namely the OSPAR List of Chemicals for Priority Action and The Endocrine Disruption Exchange (TEDX).

- The Danish EPA study used different criteria than GreenScreen to evaluate bioaccumulation. The GreenScreen thresholds used to demarcate high versus moderate bioaccumulation potential as represented by bioconcentration or bioaccumulation factors are “>1000-5000” and “>500-1000”, respectively. The Danish EPA study used thresholds of “>2000-5000” and “>500-2000” instead. The stated reason was to “reflect more correctly the EU PBT and vPvB category delimitations”. In addition, the criteria for low and very low bioaccumulation potential as reflected by Log K_{ow} ⁴ were different than GreenScreen thresholds. In the Danish EPA study an interval for “Low” was added (>3.0 to 4.0), and the interval for “Very Low” was changed from Log $K_{ow} \leq 4$ to Log $K_{ow} \leq 3$.
- The Danish EPA study used different criteria to classify list-based information for acute and chronic aquatic toxicity. Specifically, the EU H-Statements H401 and H402 were added, while the EU R-Phrases of R51/53 and R52/53 were replaced by R51 and R52, respectively, in the list-based hazard criteria for acute aquatic toxicity. For chronic aquatic toxicity, the EU H-Statements H410, H411, and H412 were added as were the EU R-Phrases R50/53, R51/53 and R52/53 to the list-based hazard criteria. In addition, CLP (Harmonised; EU) is not included as a separate Specified List in GreenScreen.

Clean Production Action’s Response:

GreenScreen is a hazard assessment method that is designed to be protective of human health and the environment, to take a life-cycle approach⁵, and to be applied internationally. The Hazard Criteria and Specified Lists incorporated in GreenScreen are built on international precedents, are intended to be applicable globally, and were extensively peer-reviewed.

The inclusion of the physical hazard endpoints of reactivity and flammability are important to capture potential worker health and safety impacts. Incorporation of GHS and country-specific lists of GHS classifications supports the application of GreenScreen in all geographies.

GreenScreen Specified Lists do not include information that is submitted by industry without review or verification by an authoritative body, such as CLP classifications provided via C&L notifications or registration dossiers and not reviewed or verified for accuracy by ECHA. In

⁴ K_{ow} (octanol/water partition coefficient) is defined as the ratio of a chemical’s concentration in octanol divided by its concentration in water. Values of K_{ow} are unit less and usually expressed as log K_{ow} .

⁵ Considering inherent hazards during all product phases, including manufacturing and end-of-life.

GreenScreen, an assessor would include such information in his/her comprehensive review of all available data and subsequent hazard classification using a weight of evidence approach.

In terms of endocrine activity, GreenScreen requires consideration both of evidence of endocrine activity and a plausibly related adverse human health effect. For chemicals appearing on the EU Priority list or any other GreenScreen Specified List, the assessor also reviews the entire body of literature available for a given chemical, including strength of evidence for a plausibly related adverse health effect related to endocrine activity to assign a hazard classification. The Danish EPA project used the EU Priority List criteria for assigning hazards. These criteria were developed to identify chemicals for which further review and assessment is needed to understand potential for adverse human health effects related to endocrine activity. The Danish EPA project assigned a high hazard based on evidence of endocrine disrupting activity in at least one species using intact animals (Category 1 criterion for classification on the EU Priority List), and a moderate hazard based on at least some in vitro evidence of biological activity related to endocrine disruption (Category 2 criterion for classification on the EU Priority List). In summary, GreenScreen requires an additional research step for chemicals flagged as potentially impairing human health through the endocrine system beyond what was included in the assessment for the Danish EPA project.

The Danish EPA study criteria for bioaccumulation potential based on BCF/BAF resulted in less conservative criteria than GreenScreen, since the band for a moderate classification was widened in the Danish EPA project. The Danish EPA study criteria for Log K_{ow} resulted in slightly more conservative criteria than GreenScreen, since a value of 3 or less is required for a very low categorization (versus 4 in GreenScreen).

Additional Recommendations:

COWI A/S also provided recommendations on GreenScreen method modifications beyond those implemented in their research, including changes to the Benchmark criteria (i.e., finer gradation of numeric scores), consideration of mobility of flame retardant substances in polymer matrices, and incorporation of exposure considerations. On the latter point, COWI A/S suggests that certain endpoints, such as acute toxicity and acute aquatic toxicity are not relevant in many consumer product contexts and thus could be omitted. This recommendation is inconsistent with GreenScreen being a hazard assessment method that evaluates inherent hazards across all product phases including manufacturing and end-of-life, and thus the rationale for inclusion of all endpoints provided for in the method. Also, for fear of confusion and misunderstanding to broader audiences, it is critical that evaluations of substances that use an approach other than the established GreenScreen for Safer Chemical methodology do not indicate or suggest as much. **We strongly encourage that those applying GreenScreen remain true to the defined methodology so as to enable as much cross comparison of chemicals as possible—a primary philosophy underpinning the development of the GreenScreen methodology.**

Substance-Specific Comments:

Several of the flame retardant substances evaluated in the Danish EPA project have published GreenScreen Benchmark scores resulting from assessors following the GreenScreen Guidance and Resources as published by Clean Production Action. The following table provides a high-level comparison of these published GreenScreen Benchmarks™ against the scores listed in the Danish EPA report. **Clean Production Action clarifies that due to the modifications to the criteria used in the Danish EPA study and outlined above, the hazard profile scores published in the Danish EPA report are not comparable to previously published GreenScreen Benchmarks.**

Clean Production Action considers only GreenScreen Benchmarks resulting from assessments following the GreenScreen Guidance and Resources as published by Clean Production Action to be valid scores for use in standard and certification frameworks which have chosen to incorporate GreenScreen. Clean Production Action invites input from stakeholders around the world on potential GreenScreen method improvements and looks forward to continuing its work to provide a robust hazard assessment tool in support of organizational decision-making focused on transitioning the economy away from the use of hazardous chemicals.

Comparison of GreenScreen Benchmarks vs Danish EPA Scores (for flame retardant substances which have both values available)

Chemical Name	CAS No.	GreenScreen Benchmark ⁶	Danish EPA Score	Source of Difference
Ammonium polyphosphate (APP)	68333-79-9	BM 3-improve (Criterion 3c)	BM 4-preferred	<p>The main difference in score is due to differences in the hazard classification for skin irritation/corrosivity. The Danish EPA report scored this endpoint low based on the original US EPA DfE Alternative Assessment (2015). Note that US EPA DfE and GreenScreen use different hazard criteria for skin irritation/corrosivity. In the GreenScreen assessment, ammonium polyphosphate was assigned a score of moderate for skin irritation/corrosivity based on test results provided by US EPA DfE which indicate ammonium polyphosphate is slightly irritating in a rabbit 24-hour occlusive patch test. This fulfills the guidance of a Category 3 Skin Irritation/Corrosivity under GHS. Additional in vitro test data available outside of the US EPA DfE assessment suggests a low hazard score. The moderate hazard score was therefore conservatively based, and reported as lower confidence within the GreenScreen assessment. Per the GreenScreen Guidance, for inorganic substances, persistence is considered only in combination with chronic hazards, and therefore the final Benchmark score assigned was 3. Even if skin irritation/corrosivity was classified as low, the highest score which could be achieved is Benchmark-3_{DG}, due to data gaps.</p> <p>The Danish EPA report concluded a score of 4 could be assigned because of a low classification for all endpoints except persistence, which is not relevant since the substance is inorganic and there are no chronic endpoint impacts. However, in their assessment, there is a Data Gap for respiratory sensitization, so a score of 4 cannot be assigned per the GreenScreen Guidance data requirements.</p>

⁶ GreenScreen Benchmark Criterion (or Criteria) met. Access the [Guidance and Resources](#) for a list of criteria for each GreenScreen Benchmark.

Chemical Name	CAS No.	GreenScreen Benchmark ⁷	Danish EPA Score	Source of Difference
Phosphonate oligomer ⁸	68664-06-2	BM 1- avoid (Criterion 1b)	BM 2- substitute	In the GreenScreen assessment, polyphosphonate oligomer was assigned a Benchmark-1 score based on very high persistence and very high bioaccumulation. The Danish EPA report follows the ratings of US EPA DfE Alternatives Assessment (2014) , which classified persistence as very high, and bioaccumulation as high. In the US EPA DfE assessment, although measured BCF values were available, estimated BAF values were incorporated for a conservative approach. Per the US EPA DfE assessment, the BAF estimates are consistent with the potential for bioaccumulation that is anticipated. Estimated BAF values of 780,000 and 64,000 for the n=1 and n=2 oligomers, respectively, were reported. In addition, an estimated fish BCF of 10,000 for the n=1 oligomer was reported. As explained in the GreenScreen assessment, since the estimated BAF and BCF values presented in the US EPA DfE assessment were above 5,000, a very high classification was assigned. Since the designation is based on estimated values, it is reported in italics within the GreenScreen assessment.
Poly[phosphonate-co-carbonate]	77226-90-5	BM 2- substitute (Criterion 2c)	BM 3- improve	A Benchmark-2 score from the GreenScreen Assessment was based on very high persistence and moderate skin and eye irritation/corrosivity. The Danish EPA report followed the ratings in the original US EPA DfE Alternatives Assessment (2014) , which categorizes poly[phosphonate-co-carbonate] as a low dermal and eye irritant. Note that US EPA DfE and GreenScreen use different hazard criteria for skin irritation/corrosivity. Thus the Danish EPA report assigned low hazards to all endpoints, except for persistence which was scored very high, resulting in a score of 3.

⁷ GreenScreen Benchmark Criterion (or Criteria) met. Access the [Guidance and Resources](#) for a list of criteria for each GreenScreen Benchmark.

⁸ Note that in the Danish EPA report the hazard information from the original US EPA DfE assessment for phosphonate oligomer is labeled as polyphosphonate (see pages 67-68). In this table we are therefore comparing the score in the Danish EPA Report to that of the GreenScreen assessment Benchmark score for phosphonate oligomer.

Chemical Name	CAS No.	GreenScreen Benchmark ⁹	Danish EPA Score	Source of Difference
Resorcinol bis-diphenylphosphate (RDP)	125997-21-9, 57583-54-7	BM 2-substitute (Criteria 2a, 2d, 2e)	BM 1- avoid	The main difference in scores was driven by different classifications for endocrine activity. In the GreenScreen assessment resorcinol bis-diphenylphosphate was assigned a score of moderate for endocrine activity based on resorcinol (CASRN 108-46-3), a suspected metabolite of RDP, which is listed as a suspected endocrine disruptor by the EU. Resorcinol is listed as a Category 1 (evidence of endocrine disrupting activity) on the EU Priority List based on thyroid effects reported in at least one species using intact animals. Resorcinol is also included within the TEDX list of potential endocrine disruptors. Resorcinol was assigned a moderate GreenScreen hazard score for endocrine activity based on: 1) the thyroid effects being reversible, and 2) a moderate score for repeat dose systemic toxicity based on thyroid effects. The score was based on data for a suspected metabolite of RDP and therefore is reported in italics within the GreenScreen assessment. In the Danish EPA report, due to the differences in hazard criteria between the two methods, a high hazard was assigned to endocrine activity due to resorcinol's listing as a Category 1 chemical on the EU Priority List. The high hazard classification for endocrine activity drove the score of 1.

⁹ GreenScreen Benchmark Criterion (or Criteria) met. Access the [Guidance and Resources](#) for a list of criteria for each GreenScreen Benchmark.

Chemical Name	CAS No.	GreenScreen Benchmark ¹⁰	Danish EPA Score	Source of Difference
Triphenyl phosphate (TPP)	115-86-6	BM 2-substitute (Criteria 2e, 2f)	BM 1- avoid	The main difference in scores was driven by different classifications for endocrine activity. In the GreenScreen assessment, triphenyl phosphate (TPP) was assigned a score of moderate for endocrine activity based on impaired reproductive effects in zebrafish and positive in vitro activity presented within US EPA DfE Alternatives Assessment (2014) . Additional data presented in the US EPA DfE assessment suggest a correlation of TPP in house dust and decreased sperm counts in humans, however, it is not known if TPP or other substances found in the household dust caused or contributed to the reported toxicity. Triphenyl phosphate was not assigned a high score for endocrine activity as there is no evidence that the reported effects are plausibly related to adverse effects for carcinogenicity, reproductive toxicity, developmental toxicity and/or systemic toxicity (repeated dose, typically, thyroid). Professional judgment was used in assigning the hazard score based on the available data and therefore the score is reported in italics. Based on the US EPA DfE data, endocrine activity was assigned a high hazard rating in the Danish EPA report based on “several primary studies and a few secondary sources listed in the report demonstrate effects on endocrine activity in vitro as well as in vivo”.

¹⁰ GreenScreen Benchmark Criterion (or Criteria) met. Access the [Guidance and Resources](#) for a list of criteria for each GreenScreen Benchmark.