

July 13, 2022

The Honourable Steven Guilbeault
Minister of the Environment and Climate Change
C/o Christina Paradiso, Executive Director
Chemicals Management, Environmental Protection Branch
Environment and Climate Change Canada
Gatineau, Quebec, K1A 0H3
Interdiction-prohibition@ec.gc.ca

Re: Proposed Prohibition of Certain Toxic Substances Regulations, 2022 – *Canada Gazette*, Part I, Volume 156, Number 20 (May 14, 2022)

Dear Minister Guilbeault:

The American Chemistry Council's North American Flame Retardant Alliance ("NAFRA")¹ hereby files a Notice of Objection and submits a request that a Board of Review be established under section 333 of the Canadian Environmental Protection Act ("CEPA") in respect of the proposed *Prohibition of Certain Toxic Substances Regulations, 2022* ("PCTSR" or "draft Regulation") published in the May 14, 2022 *Canada Gazette*, Part I, Volume 156, Number 20 as that draft Regulation relates to decabromodiphenyl ethane ("DBDPE") and polybrominated diphenyl ethers ("PBDEs").

This Notice of Objection and request for a Board of Review (the "Notice" or "submission") is being filed, and the request that a Board of Review be established is being made for several reasons.

NAFRA continues to fundamentally disagree with the conclusions of Environment and Climate Change Canada ("ECCC" or "Department") and Health Canada ("HC") as set out in the Final Screening Assessment of DBDPE. New scientific evidence has been adduced, and is referred to in this Notice, which is sufficient to cause the Minister to change his opinion on whether DBDPE is "toxic". If DBDPE is not "toxic" then there is no jurisdiction to enact the draft Regulation. If the Minister is not prepared to revoke those portions of the draft Regulation pertaining to DBDPE, such new scientific evidence confirms that the Minister should establish a Board of Review to inquire into the nature and extent of harm due to the release of DBDPE into the environment.

¹ The American Chemistry Council's North American Flame Retardant Alliance was formed in March 2011. NAFRA members include Albemarle Corporation, ICL Industrial Products, and LANXESS. Additional information regarding NAFRA may be found at <https://www.americanchemistry.com/industry-groups/north-american-flame-retardant-alliance-nafra>.

With respect to the proposed risk management measures listed in the draft Regulation, NAFRA considers those to be unnecessary and unreasonable. Even if a Board of Review were to conclude that DBDPE had the potential to cause harm to the environment, the risk to public health and safety which would result from the implementation of those risk management measures is considerable, and alternative risk management measures not resulting in virtual elimination would be sufficient to manage the potential risk of harm posed by DBDPE. Further, the adverse effect on the Canadian economy resulting from the implementation of those risk management measures is immeasurable. In addition, even if a Board of Review were to conclude that DBDPE had the potential to cause harm to the environment, alternative risk management measures not resulting in virtual elimination would be sufficient to manage the potential risk of harm posed by DBDPE.

These, and other reasons for the filing of the Notice, are set out below.

DBDPE is not CEPA Section 64 “toxic”

The Conclusions of the Final Screening Assessment upon which the Proposed Risk Management Measures for DBDPE Rely are not Supported by the current State of the Science

This Notice includes a comprehensive list of 50 analytical, toxicological, environmental, and pharmacological studies that have been conducted on DBDPE in order to evaluate its safety and to register DBDPE, as may be required, in other jurisdictions. Each study has been provided to ECCC through the assessment process or during the comment period to assist in the evaluation of DBDPE.

In addition, NAFRA has provided ECCC with new scientific data which demonstrates the stability of DBDPE. NAFRA previously provided a summary of this new scientific data to ECCC. This Notice includes the study which provides this new scientific data, plus an independent expert opinion on the methodology used in that study, and an opinion on the validity of the results of that study. That study, the accompanying independent expert opinion, the updated opinion of Dr. Frank Gobas which takes this study into account, and the peer review of the Dr. Gobas report by Dr. Keith Solomon, a member of the Siloxane D5 Board of Review previously established by the Minister, provide compelling new scientific evidence that the conclusions of the Final Screening Assessment of DBDPE are simply wrong.

NAFRA asserts that the available science as demonstrated by these 50 studies, plus the new scientific evidence previously referred to, does not support a conclusion that would justify adding DBDPE to Schedule 1 of CEPA. It is noteworthy that of the 50 studies previously provided to ECCC not one study demonstrated the potential for DBDPE to breakdown under rigorous and lengthy testing. The additional new scientific evidence confirms the inability of DBDPE to breakdown within any reasonable period of time. Therefore, there is no basis upon which ECCC should seek the virtual elimination of DBDPE in Canada.

This submission is elaborated upon below.

First, the state of the science does not support the finding reached in the Final Screening Assessment that DBDPE “is entering or may enter the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect.” As part of the screening assessment, ECCC used decabromodiphenyl ether (“decaBDE”) as a structural analogue for DBDPE to conduct “read-across of certain physical-chemical properties, as well as to predict substance behaviour in the environment.” The conclusion reached by ECCC with respect to DBDPE relied on modelling techniques with decaBDE serving as an analogue for DBDPE. There are however, no scientific studies or data upon which ECCC relies that support the use of decaBDE as an analogue to confirm the results of the modelling of DBDPE. To the contrary, all available evidence demonstrates that DBDPE behaves entirely differently than decaBDE.

Second, in addition to the 50 studies discussed above, there is new scientific information since the Final Screening Assessment was published in the May 11, 2019, *Canada Gazette*, Part I, that was not available and therefore not evaluated by ECCC or HC during the screening assessment. This additional scientific information provides a sufficient justification for the Minister to reconsider the conclusion reached in the Final Screening Assessment that DBDPE is “toxic” under CEPA.

This additional scientific information includes the results of a 336-hour study modelling the photolytic degradation of DBDPE within high impact polystyrene (“HIPS”) in the Canadian environment. This information has been shared with ECCC. The conclusions from that study are that DBDPE has a long half-life under realistic photodegradation conditions, that any formation of lower brominated products from DBDPE is negligible and are not the species of concern expressed by ECCC, and that lower form brominated products can be prevented with the help of ultraviolet (UV) absorbers and light stabilizers.

Building on that research, a 2,000-hour study was conducted extending the modelling of the photolytic degradation of DBDPE within HIPS and polypropylene (PP) in the Canadian environment.² Preliminary results from this study have previously been shared with ECCC, and the draft manuscript of the study which is being prepared for publication is included with this Notice.

The 2,000-hour study supports and extends the findings from the 336-hour study. The conclusion is that DBDPE has an even longer half-life under these more realistic photodegradation conditions. The study followed the ASTM D7869 Standard and the results are reliable. Attached to this Notice is an independent expert opinion confirming that the proper methodology was

² Mathur, RS et al. Is Ethane Bis(pentabromophenyl) an Environmental Concern? Assessing the Impact of Photolytic Degradation in Plastics, Albemarle Corporation, 2022.

used for the study and the proper methodology was followed. That expert opinion confirms the validity of the conclusions of that study.

Conclusions from the 2,000-hour study confirm that as a polymer additive, photolytic degradation of DBDPE is orders of magnitude slower in resins than in dilute matrices under photolysis, and UV stabilizers mitigate the slow degradation of DBDPE even further. This conclusion also relates directly to the draft Regulation. Rather than seeking virtual elimination, a reasonable risk management measure, if it is determined that DBDPE is “toxic” would be to require the use of ultraviolet (UV) absorbers and light stabilizers in the resins which incorporate DBDPE. Virtual elimination is not necessary and is unreasonable.

Third, attached to this Notice is the updated independent expert opinion of Dr. Frank Gobas of Simon Fraser University. Dr. Gobas is a recognized and respected toxicologist, and his opinion is invaluable for the purposes of making a final determination on whether or not DBDPE is “toxic” under CEPA. Dr. Gobas was initially retained by NAFRA in 2020, to conduct an independent third-party review of the available scientific reports relating to DBDPE, as well as the draft and final screening assessments for DBDPE, for the purpose of providing an expert opinion on the validity of the approach taken and conclusions reached by ECCC with respect to the Final Screening Assessment for DBDPE. Dr. Gobas was retained by NAFRA to update his opinion to consider the new scientific information on DBDPE. His updated report is attached. As a recognized and respected toxicologist, Dr. Gobas’ views are also invaluable for the purposes of providing an opinion on the appropriateness of the proposed risk management measure.

Below are several of the conclusions from Dr. Gobas’ earlier independent review:

- DecaBDE is not a good read-across substance for the purpose of estimating the rate of potential debromination of DBDPE;
- Guidelines and recommendations for applying a read-across approach exist but were not adequately followed by ECCC in the Final Screening Assessment; and,
- The Final Screening Assessment does not include evidence to substantiate that lower-form DBDPE products enter the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect.

Dr. Gobas emphasized that DBDPE cannot form the same transformation products as decaBDE. He noted that while DBDPE can theoretically form lower brominated products, these lower brominated products are different from those formed by decaBDE and do not include brominated dibenzo-p-dioxins, dibenzofurans, or diphenyl ethers. The inherent toxicity of lower brominated products from DBDPE had not been demonstrated. Furthermore, Dr. Gobas opined that degradation rates of DBDPE are very slow. He concluded that it is unlikely that

transformation products of DBDPE are formed in quantities or concentrations that can have an immediate or long-term harmful effect on the environment or its biological diversity.

Dr. Gobas' updated opinion confirms his prior opinion and offers the following conclusions:

The evidence and insights I present in this report shows that DBDPE does not and cannot transform to lower brominated products in a manner similar to decaBDE and that decaBDE is not a good a read-across for the formation of DBDPE debromination products.

Furthermore, there is no credible evidence to substantiate that debrominated DBDPE products enter the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect. Also, DBDPE does not contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products. As ECCC concludes itself, the only lower brominated (B)DPEs that have the potential of being formed (albeit at extremely slow rates) are probably baseline toxicants, which are among the least inherently toxic substances in nature. And among those substances, chemicals like DBDPE and some of its are debromination products are even less inherently toxic because they cannot even cause baseline toxicity.

I have to conclude that a Board of Review is needed not only to reach a correct conclusion regarding the risk of DPDBE to environmental and human health, but also to ensure that other substances are assessed correctly. This is because:

1. A substance with a long record of safe use and which has been subjected to many toxicological studies, is considered to be toxic by ECCC in absence of any evidence of toxicity.
2. ECCC struggles to make evidence-based decisions for DBDPE. Despite a thorough compilation of the results from many scientific studies that accompanies the assessment, ECCC relies on questionable theories and an inappropriate use of the precautionary principle in situations where there is no evidence of threats of serious or irreversible damage.
3. It is crucial for the Government of Canada to be credible in its assessment of chemicals and maintain the confidence of Canada's population and stakeholders that is needed to develop effective policies that protect environment and human health.

This opinion concludes that the rationale for determining that DBDPE meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999), i.e., *"that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE (p. 32)."*, and that *"DBDPE may contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated*

(B)*DPEs in the environment*” is seriously flawed and should be revisited to reach an accurate environmental assessment of DBDPE. A Board of Review is a logical step towards that.

Dr. Gobas’ conclusions have been confirmed by Dr. Keith Solomon. Dr. Solomon is an internationally recognized toxicologist. His expertise, and the respect he has earned over his distinguished career was recognized by the Minister when Dr. Solomon was appointed to the Siloxane D5 Board of Review.

Dr. Solomon was asked to conduct an independent peer review of Dr. Gobas’ opinion. Following his review Dr. Solomon finds that Dr. Gobas’ conclusions with respect to DBDPE are correct. Specifically, Dr. Solomon reaches the following conclusions:

- ECCC incorrectly used read-across data on decaBDE to extrapolate the potential for DBDPE to undergo photolysis to form potentially toxic products, such as brominated furans.
- There is no evidence to show that DBDPE breaks down in the environment and forms potentially toxic products in a similar way to decaBDE.
- DBDPE does not meet the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999). DBDPE is essentially unreactive and, even under photolysis, will not form potentially toxic substances. Photolysis is also not expected in plastic products containing DBDPE and these plastics are usually formulated with UV absorbers to protect against environmental degradation of the plastic polymer.
- DBDPE is of low toxicity to mammals and aquatic organisms. This is consistent with a lack of absorption in the gut of mammals and *de minimis* bioavailability in water because of low solubility.
- While DBDPE might reach soil or surface water it will adsorb strongly to particulate matter and sediments thereby further reducing the potential for exposure of biota in the environment. This adsorption will further minimize exposures to solar radiation and reduce photolytic breakdown.
- There is no evidence to show that DBDPE and products containing this material present a risk to the environment and human health in Canada.

In Dr. Solomon’s opinion, a Board of Review would, in short order, reach the same conclusion as Dr. Gobas and himself.

Next, the National Academy of Sciences, Engineering, and Medicine (“NAS”) published a study report³ in May 2019 to determine if organohalogen flame retardants (“OFRs”) – which includes DBDPE – could be divided into subgroups based on similar chemical structures or physicochemical properties for the purposes of further assessment. NAS recommended dividing 161 OFRs into 14 subclasses. It is noteworthy that in the study, NAS grouped DBDPE and decaBDE into separate subclasses with DBDPE in the polyhalogenated benzene aliphatics and functionalized subclass and decaBDE in the polyhalogenated diphenyl ethers subclass. This finding further supports the position that it is not appropriate to use decaBDE as a surrogate for DBDPE to draw any conclusion regarding potential breakdown products in the absence of supporting studies.

A GreenScreen Risk Assessment for DBDPE was conducted in December 2021 with the compound assigned a Benchmark-2 score.⁴ By comparison, decaBDE has a List Translator 1 score (equivalent to a Benchmark-1 score) meaning the hazard classification meets one or more of the GreenScreen Benchmark-1 criteria and would most likely be a Benchmark-1 chemical if given a full GreenScreen Risk Assessment. In the GreenScreen Risk Assessment for DBDPE it notes that, “while both DBDPE and Deca have the same degree of bromine substitution, one is an unsaturated alkane (*i.e.*, ethane) and the other is an ether. The potential for biological/metabolic differences may be significant, as indicated by differing GreenScreen scores obtained for certain endpoints.” Again, this further indicates that decaBDE has limited value as a structural analogue for DBDPE

Last, in the ECCC report on *Polybrominated Diphenylethers in Fish and Sediment* published in January 2020, ECCC states that “sediment sampling in many drainage regions of Canada does not go back far enough to establish long-term trends.”⁵ This lack of data establishing long-term trends for decaBDE further reinforces the fact that DBDPE does not meet the criteria for listing under Schedule 1 and therefore does not require risk management measures. If DBDPE were truly degrading in the environment, relevant monitoring data for the compounds analyzed would be expected to demonstrate the increasing presence of substances of concern in the environment. However, this real-world monitoring data directly contradicts the modelling and assumptions that were the basis for the Schedule 1 listing and provides an additional rationale for withdrawing the listing and the proposed risk management measures.

³ National Academies of Sciences, Engineering, and Medicine. 2019. A Class Approach to Hazard Assessment of Organohalogen Flame Retardants. Washington, DC: The National Academies Press. doi: <https://doi.org/10.17226/25412>.

⁴ Gradient. GreenScreen® Assessment for [Decabromodiphenyl ethane; DBDPE (CAS # 84852-53- 9)]; Prepared for: American Chemistry Council: December 2021.

⁵ ECCC, “*Polybrominated Diphenylethers in Fish and Sediment: Canadian Environmental Sustainability Factors*,” January 2020. <https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/pbde-fish-sediment/2020/PBDE-fish-sediment-en.pdf>.

NAFRA has engaged with ECCC throughout the regulatory process for DBDPE. The submission of the 50 studies considered as part of the Final Screening Assessment, along with the new scientific information that has been developed since the Final Screening Assessment, supports the conclusion that DBDPE is **not** “toxic” under CEPA.

Final Screening Assessment for DBDPE Ignores the “Weight of the Evidence”

Section 76.1 of CEPA requires that ECCC and HC apply both the weight of evidence and the precautionary principle in conducting the evaluation of the scientific evidence relating to any particular substance. Section 76.1 does not give precedence to either of these two principles. The application of the precautionary principle is not stated or intended to govern decision-making.

The conclusion reached in the Final Screening Assessment that DBDPE has the potential to transform into lower brominated products that could pose a risk to aquatic organisms conflicts with the proper application of the weight of evidence approach and has not been substantiated. ECCC reached its conclusion regarding the potential for breakdown of DBDPE based on a theory that the DBDPE would behave in the same way as decaBDE. That conclusion is inconsistent with the available evidence on DBDPE.

The approach taken by ECCC is contrary to the statutory requirement to apply the weight of evidence approach. DBDPE is very different scientifically and structurally than decaBDE. Thus, the use of decaBDE as a proxy for DBDPE in computer modelling to draw this conclusion of potential breakdown products in the absence of any supporting studies is not appropriate and based on faulty assumptions given their different molecular structures.

Proposed Risk Management Measures set out in the draft Regulation are Unnecessary and Unreasonable

Proposed Risk Management Measures May Lead to Severe Risk to Public Health and Safety

DBDPE performs a valuable function by reducing the potential for flammability when it is used as intended in products. Those products include not just consumer devices and appliances, but also include airplanes and motor vehicles. In the absence of alternatives, the prohibition poses a genuine risk of increasing flammability and shock risk for products, thereby increasing the risk to public health and safety.

Product manufacturers must balance the need to meet consumer demand for overall performance with the need to ensure that those products meet relevant safety standards. Synthetic materials such as plastic have revolutionized product designs for electrical and electronic equipment. Manufacturers use flame retardants in synthetic materials to ensure performance goals. For example, flame retardants are used in casings and enclosures for

electrical and electronic equipment to protect from fire and shock risk. If left untreated, these materials are flammable, so flame retardants provide an important layer of fire safety.

There are hundreds of end-product standards for electrical and electronic equipment. For example, Underwriters Laboratories (UL) 746C can require electrical and electronic products with larger enclosures to undergo a specific test that assumes a flame threat occurs outside of the enclosure.⁶ In addition, product standards can contain additional or stricter requirements than UL 746C, such as an enclosure needing a minimum rating of UL 94 V-1 or V-0 for flammability.⁷

Fire safety standards should be viewed as minimum requirements for flammability and products can go beyond those standards. Product manufacturers use flame retardants such as DBDPE to meet or exceed minimum flammability requirements based on their own needs for safety and performance. For instance, product manufacturers may conclude that an external fire threat is a risk for their product (from a candle or other flame source) and want their product to exceed minimum requirements for horizontal burning or may determine that an internal risk may warrant higher flammability requirements than the minimum flame rating allowed in a standard.

The virtual elimination of DBDPE in the absence of a foreseeable alternative, even with the extended dates as set out in the draft Regulation, therefore poses a very real, and very substantial risk to the health and safety of all Canadians. This is a risk which is not justified by the potential risk of harm due to the release of DBDPE into the environment as determined by ECCC.

Proposed Risk Management Measures for DBDPE are Not Aligned with Other Regulatory Agencies or Agreements

The proposed risk management measures for DBDPE as set out in the draft Regulation are an outlier globally. No other regulatory authority in the world has proposed risk management measures for DBDPE as sweeping as those set out in the draft Regulation. Canada is acting alone to prohibit the use of DBDPE. By way of example, the United States Environmental Protection Agency (U.S. EPA) is not currently conducting a risk evaluation for DBDPE and is not contemplating risk management measures.

ECCC has noted that Canada is a party to the Stockholm Convention on Persistent Organic Pollutants (POP), and that the proposed risk management measures would allow Canada to meet “its international commitments implementing amendments to the Stockholm Convention.” Yet, DBDPE is not listed as a POP under the Stockholm Convention.⁸ Further, DBDPE is not under

⁶ UL 746C specifies standards for parts made of polymeric materials that are used in electrical equipment and describe the various test procedures and their use in the testing of such parts and equipment.

⁷ UL 94 specifies standards for safety tests for flammability of plastic materials in devices and appliances.

⁸ Stockholm Convention on Persistent Organic Pollutants, All POPs Listed in the Stockholm Convention, <http://chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx>, Accessed on July 10, 2022.

consideration by the POPs Review Committee for potential listing under the Convention.⁹ The rationale that risk management measures for DBDPE are needed for Canada to meet its commitments to the Stockholm Convention is not supported by the facts.

ECCC also cites meeting the goals of the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA) as a justification for its proposed risk management measures. However, DBDPE is not listed as a Chemical of Mutual Concern as part of the agreement, and therefore risk management measures for DBDPE are not needed to comply with the GLWQA.¹⁰ Accordingly, neither rationale justifies the proposed risk management measures.

The Minnesota Department of Health collected information on DBDPE in 2017 as part of its screening process for Contaminants of Emerging Concern (“CEC”) program. Substances nominated under the CEC program are screened and ranked based on their toxicity and presence in Minnesota waters. DBDPE is not listed as a priority chemical by the Minnesota Department of Health¹¹ and has not been detected in potential drinking water sources in Minnesota.¹²

Last, the Final Screening Assessment of DBDPE, as well as the Proposed Order to add the substance to Schedule 1 of CEPA published in the June 29, 2019, *Canada Gazette*, Part I Notice, and the subsequent draft Regulation are inconsistent with the U.S.-Mexico-Canada Agreement (USMCA), which requires “a risk-based approach to the assessment of specific chemical substances and chemical mixtures.”¹³

Since the draft Regulation for DBDPE is inconsistent with regulations in other jurisdictions there will be significant negative effects on the supply chain for future products being made or imported into Canada. Manufacturers rely on a global supply chain for components and subcomponents. Any proposed regulations should take this into account and to the maximum extent possible align with existing agreements and regulations in other jurisdictions.

⁹ Stockholm Convention on Persistent Organic Pollutants, Chemicals Proposed for Listing Under the Convention, <http://chm.pops.int/TheConvention/ThePOPs/ChemicalsProposedforListing/tabid/2510/Default.aspx>. Accessed on July 10, 2022.

¹⁰ Canada-U.S. Great Lakes Water Quality Agreement, Annex 3: Chemicals of Mutual Concern, <https://binational.net/annexes/a3-2/>. Accessed on July 10, 2022.

¹¹ Minnesota Department of Health, Priority Chemical List, <https://www.health.state.mn.us/communities/environment/childenvhealth/docs/pclist/pctable.pdf>. Accessed on July 10, 2022.

¹² Minnesota Department of Health, Contaminants of Concern; DBDPE Screening Profile, <https://www.health.state.mn.us/communities/environment/risk/docs/guidance/dwec/screening/dbdpe.pdf>. Accessed on July 10, 2022.

¹³ U.S.-Mexico-Canada Agreement, Article 12.A.4: Enhancing Regulatory Compatibility, https://ustr.gov/sites/default/files/files/agreements/FTA/USMCA/Text/12_Sectoral_Annexes.pdf.

Proposed Risk Management Measures May Lead to Supply Chain Disruptions

Product manufacturers operate in a global regulatory environment and must consider a broad range of product safety and design factors. This includes considerations related to product certification, performance, use and end of life, and even chemical registration. These regulatory, design, and performance requirements are addressed through a complex global supply chain for components and subcomponents.

Prohibiting the use, import, and sale of DBDPE without a suitable alternative available will be costly for product manufacturers even if an alternative to DBDPE becomes available and is able to be certified within the timeframe set out in the draft Regulation for the ban on the manufacture, import and use of DBDPE. They will have to redesign, reformulate, recertify, and remanufacture products only for Canada since it is the only regulatory authority in the world proposing such sweeping restrictions on the substance. As businesses continue to recover from the impacts of an unprecedented global pandemic, including detrimental supply chain complications, it is not the time to be adding unnecessary regulatory burdens that are not supported by the state of the science.

A 2020 socioeconomic study commissioned by ECCC on DBDPE in the Canadian market¹⁴ noted that “at this time, effective fully tested alternatives are not currently known for many critical applications.” The study estimated that between 500 and 1,500 metric tons¹⁵ of DBDPE were imported into Canada in 2018. Of that amount, approximately 75 percent was imported in resins, manufactured articles, and finished products, while approximately 25 percent was imported as a raw material for manufacturing purposes.

Imported electrical and electronic products, including wire and cable products, were responsible for 68 percent of DBDPE imports into Canada. Imported DBDPE in transportation equipment primarily functions as a flame retardant in wire and cable components, and other electronic and electrical components of finished vehicles. The majority of DBDPE imported as a raw material was compounded into resins and subsequently used to manufacture wire and cable products, wire connection products, and electrical enclosures. Between 100 and 500 metric tons of DBDPE was exported, primarily in wire and cable products and transportation equipment.

The 2020 socioeconomic study commissioned by ECCC correctly notes that certain levels of flame retardancy as dictated by broad-market standards such as the Canadian Standards Association (CSA) and UL are largely achieved through the addition of chemical flame retardants. Furthermore, achieving the mandated flame retardancy requires trade-offs with the performance of the polymeric material, which puts at risk the product’s ability to meet other

¹⁴ ECCC conducted a third-party socio-economic study regarding DBDPE and Dechlorane Plus in the Canadian marketplace that was completed on January 25, 2020. A copy of the report is included in the appendix.

¹⁵ A metric ton is a unit of mass equaling 1,000 kilograms.

critical product performance standards. This emphasizes the complex nature of finding and developing suitable alternatives when flame retardants are banned but the flammability requirements remain, rightfully, stringent. The timelines for the implementation of the ban on the manufacture, import and use of DBDPE as set out in the draft Regulation fail to fully account for the time necessary to develop, certify for use, and incorporate an alternative substance into the supply chain and are therefore arbitrary and unreasonable.

The resin imported into Canada which incorporates DBDPE also contains UV stabilizers further minimizing the negligible potential for DBDPE to enter the environment. If any risk management measures are required to ensure that only a *de minimis* quantity of breakdown products of DBDPE have the potential to enter the environment, then the requirement that any resin containing DBDPE being manufactured or imported into Canada contain a UV stabilizer should be more than sufficient as a risk management measure.

Notwithstanding that the potential for debromination of DBDPE remains unproven by ECCC to occur, for the DBDPE being imported into Canada as a raw material, rather than virtual elimination, a reasonable alternative is to employ a process not unlike that used in the case of the Pest Control Products Act. Prior to approval of importation, manufacture or use, a review of the related processes could be required to be undertaken to ensure that there are adequate safeguards to prevent a release into the environment, and a condition of approval could be a requirement to ensure that those safeguards are in place.

In short, virtual elimination of DBDPE is not necessary or reasonable.

ECCC suggests that its consultations with industry stakeholders have helped it develop permits and exemptions to address the lack of available alternatives to DBDPE. However, these permits and exemptions are insufficient in addressing the lack of available alternatives for DBDPE. With respect to the system of permits proposed in the draft Regulation, the current proposal that the permits are only issued for one year at a time and are only able to be renewed for a limited number of times creates enormous problems for industry stakeholders. Experience with comparable permit processes such as Essential Purpose Permits issued by ECCC pursuant to the *Ozone-depleting Substances and Halocarbon Alternatives Regulations* of CEPA has established that there is considerable uncertainty as to the degree of detail required by ECCC in the application for any such Permit, considerable uncertainty as to the length of time required for ECCC to review any application, and considerable uncertainty as to whether or not a permit will even be issued. These uncertainties are unacceptable. These uncertainties are unlikely to give any industry stakeholder comfort regarding the continued importation, manufacture, or use of DBDPE.

ECCC notes several times in the draft Regulation that there is a lack of data and certainty regarding cost and availability of alternatives to DBDPE for some critical applications, and

consequently that compliance costs have not been estimated for proposed risk management measures affecting wire and cable, automotive products, and other applications.

Polybrominated Diphenyl Ethers

Proposed Risk Management Measures for PBDEs do not Align with Global Regulations and Restrictions

As mentioned earlier for DBDPE, it is also important that risk management measures for other substances align with global agreements and regulations. That is true for PBDEs, a group of flame retardants which have largely been phased out in Canada and around the world and are no longer being produced. At present, Canada largely prohibits the manufacture, use, sale, offer for sale, and import of PBDEs, including decaBDE, and all products that contain PBDEs except for manufactured items. Canada's current regulations for PBDEs are largely consistent with international regulations for PBDEs.

ECCC proposes eliminating the exemption allowing the manufacture, use, sale and import of manufactured items containing PBDEs with only a few exceptions. In addition, the presence of each PBDE congener (e.g., decaBDE, octaBDE, etc.) in a substance, mixture, polymer, or resin is proposed to be incidental at a concentration less than or equal to 10 parts per million (ppm). The presence of PBDE congeners in all other products is proposed to be incidental when the total concentration of all congeners is less than or equal to 500 ppm.

In contrast, the European Union's Restriction on Hazardous Substances (RoHS) requires electrical and electronic products to contain less than 1,000 ppm or 0.1% of PBDEs.¹⁶ Further illustrating the complexity in finding alternatives for some substances, although five PBDEs are listed as POPs by the Stockholm Convention, all of them still have some specific exemptions on a time-limited basis. U.S. EPA is also considering additional risk management measures for decaBDE, with a proposal for a new rulemaking expected in Spring 2023 that builds on the risk management rules that took effect in January 2021.¹⁷

The proposed risk management measures for PBDEs could put Canada at odds with some of its largest trading partners and consideration should be given to global regulatory alignment, circularity goals, and potential disruptions to critical sectors in the country.

¹⁶ European Commission, Annex II to the Restrictions on Hazardous Substances (RoHS) Directive 2011/65/EU, page L174/100. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0065&from=EN>.

¹⁷ 86 Federal Register 880

Conclusion

The proposed risk management measures for DBDPE as presented in the draft Regulation has the potential to result in serious risk to public health and safety and are likely to cause significant socioeconomic impacts, including severe disruptions to global supply chains. The Final Screening Assessment determination for DBDPE upon which the proposed risk management measures rely is not supported by the state of the science, is not aligned with global efforts, and did not appropriately consider and apply the weight of evidence. Furthermore, new evidence which has been developed since the Final Screening Assessment, including the photolytic degradation and NAS studies, do not support either the finding that DBDPE is “toxic” under CEPA and do not support the proposed risk management measures.

Based upon the facts and arguments set out above we ask the Minister to appoint a Board of Review to “inquire into the nature and extent of danger” posed by DBDPE and PBDEs.

Sincerely,

A handwritten signature in black ink, appearing to read "Ben Gann". The signature is fluid and cursive, with the first name "Ben" and last name "Gann" clearly distinguishable.

Ben Gann

Director, Chemical Products & Technology
American Chemistry Council

On behalf of the North American Flame Retardant Alliance

1 Is Ethane Bis(pentabromophenyl) an environmental
2 concern? Assessing the impact of photolytic
3 degradation in plastics

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8 ABSTRACT

9 Ethane-bis(pentabromophenyl) (EBP), also called decabromodiphenyl ethane (DBDPE), is a
10 versatile flame retardant used in electronics, wires and cables, textiles, construction materials and
11 other applications to meet fire safety standards. While EBP is itself nonhazardous, there are
12 concerns that its decomposition products may be harmful. One potential decomposition pathway
13 is photolytic degradation. Previous studies have focused primarily on EBP degradation kinetics
14 in dilute solvent matrices. However, few studies have examined EBP degradation in its intended
15 use as a polymer additive in solid matrices. In this paper, we present photolytic studies of EBP in
16 high-impact polystyrene (HIPS) and polypropylene impact copolymer (PP). The kinetics of
17 photolytic debromination in HIPS are orders of magnitude slower than those in dilute systems,
18 with calculated half-lives of more than 200 years vs. minutes in solution. Perhaps more
19 importantly, there is no subsequent debromination to the octabrominated congeners and lower.
20 No evidence of debromination is seen in PP, which confirms that matrix effects are important.
21 EBP is much more photolytically stable in resins than decabromodiphenyl ether (DecaBDE), and
22 read-across comparisons between the two are misleading.

23 KEYWORDS

24 Photolysis, debromination, DBDPE, EBP, flame retardant, kinetics, DecaBDE, degradation

25 SYNOPSIS

26 Photodegradation of ethane-bis(pentabromophenyl) in polymers is very slow and does not form
27 lower brominated species of environmental concern.

INTRODUCTION

Flame retardants (FRs) lower the fire risk of plastics that are used in many commercial applications, such as electronic enclosures, wires and cables, and building materials. For many applications, the use of FRs in plastic formulations is required to meet fire safety requirements specific to the application to facilitate product safety. There are different types of FRs, and there are a multitude of ways to describe them. Some FRs are blended with polymers and do not affect the chemical nature of the polymer matrix, while others are reactive and become an integral part of the polymer.^{1,2}

In recent years, certain FRs have faced environmental scrutiny and are now phased out from product use. Examples such as decabromodiphenyl oxide (also known as decabromodiphenyl ether, DecaBDE, Decabrom, DBDPO and BDE-209) now face restrictions, and alternative FRs have been proposed.^{3,4} One replacement is decabromodiphenyl ethane (EBP or DBDPE), a versatile and well-studied flame retardant suitable for many applications.⁵ EBP has been classified as structurally similar to DecaBDE in risk assessments because of structural similarities,^{4,6} even though studies have shown major differences in physical properties and degradation behavior.⁷⁻¹⁰ The National Academy of Sciences (NAS) has also weighed in on this and cautioned against grouping all chemicals into one class.¹¹

A key part in assessing the environmental impact of FRs is to assess how they are used in their end-use applications and the associated product life cycles. FRs are formulated into polymers for product use; thus, the fate of the FR in the polymer formulation provides a more accurate assessment of FR exposure to the environment. There are five degradation pathways that must be considered when looking at the end-use application and potential for environmental impact: hydrolytic, thermal, oxidative, photolytic and biological. A recent study of a polymeric

brominated FR identified thermal and oxidative pathways as relevant and photolytic pathways as less relevant based on the complete product life cycle.¹² Recycling studies¹³ and product data¹⁴ show that EBP exhibits excellent thermal and oxidative stability for product applications. Previous photolytic degradation studies of EBP showed degradation in various solvents and in the pure form,^{7,15-18} but these do not reflect relevant product lifecycle scenarios since the polymer resin can dramatically influence degradation for the FR additive. A previous study of EBP in high-impact polystyrene (HIPS) showed negligible degradation after sunlight exposure, in contrast to DecaBDE, which showed a high degree of degradation.¹⁰

In this article, we focus on the photolytic performance of EBP as a polymer additive in polypropylene (PP, impact copolymer) and HIPS polymers. These studies used accelerated UV exposure that followed ASTM D7869 for long-term UV exposure under weather conditions. Kinetic half-life estimates and qualitative assessments of species formation after exposure were obtained. UV degradation was confined to micron depths on the polymer surface, and structural analysis confirmed that the EBP degradation processes were different than those of DecaBDE.

MATERIALS AND METHODS

General. HIPS (Kumho 450W HIPS), PP (LoneStar impact copolymer), and talc (Mistron Vapor R) were obtained from commercial sources. Antimony trioxide (Brightsun HB, ATO, 99.6+%) was purchased from Minmetals. The EBP used in this study was SAYTEX® 8010, produced commercially at Albemarle's plant in Magnolia, Arkansas.

Extrusion of the compounds was carried out on a Werner & Pfleiderer (Coperion) ZSK30 (30 mm) twin screw extruder. Test parts were produced on a Boy 30A (35 ton) injection molding machine. The HIPS compound consisted of resin, 12% EBP and 4% ATO by weight, with a

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small amount (0.2%) of PTFE added as a drip suppressant. The PP compound contained 22.9% EBP, 7.6% ATO and 14% talc.

The test parts were photolyzed in an Atlas Ci4000 Weatherometer equipped with a Xenon 35/65 lamp using a Right Light Ci4000/Ci4400 inner and quartz Ci4k outer filter operating at 340 nm. Water was supplied to the instrument through a Culligan purification system. The initial 336-hour study was conducted by modifying ASTM D4459,¹⁹ which is an indoor method, using a higher irradiance level (0.70 W/m² vs. 0.35 W/m²). The 2000-hour study followed ASTM D7869.²⁰

Specimens for optical microscopy were prepared on a Struers Abramin polisher using silicon carbide (800, 1200 and 2400 grit grinding paper, in sequence). Images were obtained on an Olympus SZ61 optical microscope.

FTIR spectroscopy was conducted on a Nicolet 6700 instrument equipped with a diamond ATR cell. Bromine values were obtained using the Schöniger method²¹ and neutron activation analysis (NAA) carried out on the SLOWPOKE reactor at the Ecole Polytechnique de Montréal.

Flammability testing according to the UL 94 vertical testing standard²² was conducted in an Atlas HVUL2 flame chamber.

Chromatographic Analysis. Analyses for the initial 336-hour study were carried out on an Agilent 1290 HPLC instrument equipped with a UV diode array detector and a 6130 Single Quadrupole mass spectrometer, while analyses for the 2000-hour study were conducted on an Agilent 1290 UHPLC instrument equipped with a UV diode array detector and a 6546A high resolution Q-TOF-MS.

Samples for analysis were first cryoground in a Spex SamplePrep 6875D cryomill at liquid nitrogen temperatures. Subsequently, approximately 15-20 mg of the powder was combined with

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80 mL of HPLC grade tetrahydrofuran (THF) in a 100-mL volumetric flask and sonicated for a total of 45 minutes in three 15-minute intervals. For HIPS compounds, the resin and FR completely dissolved, but this was not the case for the PP compounds. After cooling to room temperature, additional THF was added to bring the volume to 100 mL. Approximately 2 mL of this solution was filtered using a 0.2 μ m, HPLC-grade PTFE syringe filter. The solution was then injected into the HPLC instrument.

The SAYTEX® 8010 standard and Br4 to Br10 standard mixture, prepared by combining individually synthesized compounds, were dissolved using a similar procedure. Approximately 15-20 mg of standard was dissolved in a 250-mL volumetric flask. THF was added below the mark, and the sample was sonicated for 45 minutes to give a clear solution. The flask was allowed to cool to room temperature, and additional THF was added to the mark. Further dilutions were made to prepare the concentrations needed to build calibration curves. Figure 1 provides a representative chromatogram of the standard mixture.

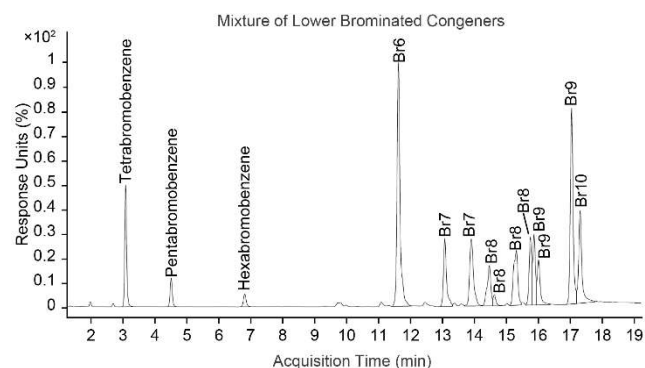


Figure 1. Standard mixture of EBP and lower brominated species.

Upon dissolution, samples were stored under ambient conditions in the dark and analyzed within a few hours of preparation.

Both LC-UV and LC-MS data were examined, with UV data giving more precision (lower standard deviation). In these studies, we assume similar response factors for Br10 and all three Br9 congeners. A comparison of relative response factors for authentic samples of Br6 (100) and Br10 (80) provided credence to this assumption. The limit of detection (LOD) and limit of quantitation (LOQ), determined according to the literature methods,^{23,24} were *ca.* 50 and 100 ppb, respectively.

Additional experimental data and details are provided in the Supporting Information.

RESULTS AND DISCUSSION

Initial Photolysis Study. In the first phase of the work, we conducted a shorter (336-hour) study in HIPS to generate samples for analytical method development, obtain an understanding of degradation products and rates, and compare to studies in dilute matrices.

The total radiant exposure was approximately 675 kJ/m², corresponding to approximately 6 months (4320 hours) of solar exposure in Western European or northern latitudes in North America.²⁵ The acceleration factor for this aging study was therefore *ca.* 12.9.

For chromatographic analysis, HPLC was used to analyze samples for degradation products and to track levels of Br10 and Br9 after thermal degradation. It should be noted that the commercial EBP (SAYTEX® 8010) used in these studies contains *ca.* 98.5-99.0% Br10 and 1.0-1.5% Br9 congeners. We obtained recoveries of above 96% for both Br9 and Br10 for formulation analysis in HIPS.

The concentration data obtained from HPLC-UV analysis for Br10 (EBP) and Br9 congeners at 0, 100, 200 and 336 hours are provided in Table 1 together with standard deviations. We observed a small decline in the EBP content and a concomitant increase in the level of Br9 congeners.

Table 1. Change in EBP and Br9 Congener Concentrations Over Time. The Br9 Value Represents the Sum of All three Br9 Isomers

Time (Hours)	EBP concentration (Area Percent)	Br9 concentration (Area Percent)
0	98.40 ± 0.05	1.60 ± 0.05
100	98.38 ± 0.05	1.62 ± 0.04
200	98.31 ± 0.07	1.69 ± 0.07
336	98.25 ± 0.05	1.75 ± 0.05

A plot of the natural log of the Br10 concentration vs. time (Figure 2) shows good linearity. Applying a first-order kinetic model, we obtained a half-life of 144,858 hours or 16.5 years in the accelerated UV aging experiment. Applying the acceleration factor, we calculated a half-life of 213 years.

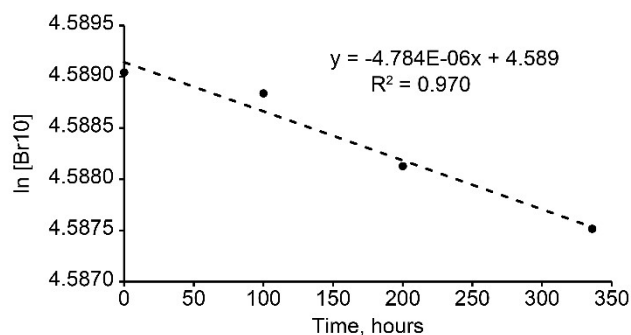


Figure 2. First-order kinetic plot of the debromination of EBP (Br10) to Br9 in high-impact polystyrene (HIPS) in the 336-hour study.

ASTM D7869 (2000-hour) Photolysis Study. The ASTM D7869 study is considered to be the best simulation of real-world conditions²⁵ and is more relevant in terms of life-cycle analysis of actual FR products and associated environmental impacts. However, the 336-hour study may be considered a more direct comparison to studies in dilute matrices because the photolysis is

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constant (i.e., the lamp is on all the time during the course of the experiment). Table 2 highlights the key differences between the initial 336-hour study and the 2000-hour ASTM D7869 study.

Table 2. A Comparison of the Experimental Conditions of the Two Photolysis Studies

Parameter	336-hour study	2000-hour study (ASTM D7869)
Lamp On All the Time?	Yes	No
Irradiance (W/m^2)	0.70	0 0.40 0.80
Total Dose (kJ/m^2)	850	3280
Water Spray	No	Yes
Water Spray with Lamp Off	No	Yes
Black Panel Temperature ($^{\circ}\text{C}$)	55	50 70
Relative Humidity, %	50	50 95
Stress Factors	Light	Light, temperature, moisture

As observed for the 336-hour study, we found a slight decrease in the Br10 concentration, although the rate of decrease was slower. Figure 3 shows an overlay of the chromatograms before and after photolysis.

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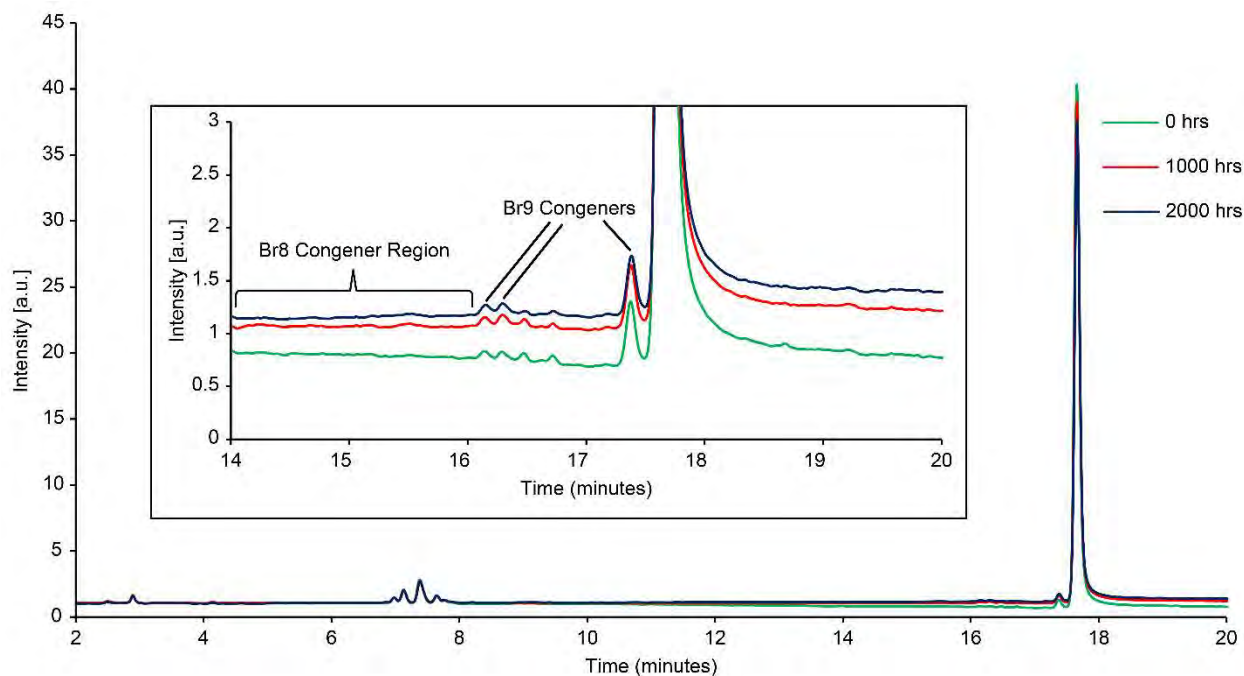


Figure 3. HPLC chromatograms of FR-HIPS compounds before photolysis and at 1000 and 2000 hours of weatherometry under ASTM D7869. The magnified region (inset) shows no Br8 congeners from photodegradation ca.ca. 100 ppb detection limit.

Figure 4 shows a plot of the natural log of Br10 concentration against time. Applying first-order kinetics, we calculated a half-life under ASTM D7869 conditions of 691,400 hours or 79 years.

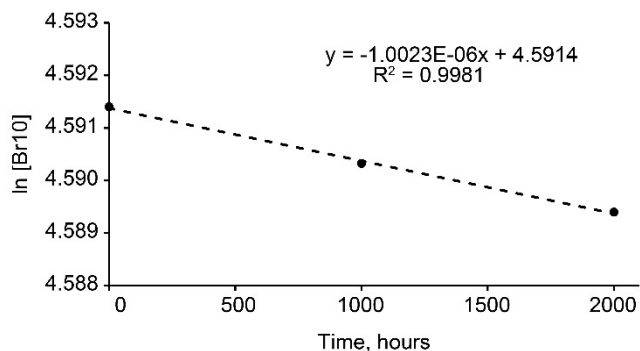


Figure 4. First-order kinetic plot of the debromination of EBP (Br10) to Br9 in HIPS in the ASTM D7869 (2000 hour) study.

To extrapolate the 79 years to a real-world value, for the 336-hour study, we used an acceleration factor (12.9) for the northern regions. However, the acceleration factor varies based on the solar intensity, which can depend on a variety of factors, including weather, temperature, latitude and altitude.

Table 3 compares the estimated annual dose of a northern climate, for example, in Western Europe or Canada, with that of a warmer southern region such as Arizona or Florida in the United States.²⁵ As expected, the half-life estimate decreases with increasing solar intensity. As in the 336-hour study, no Br8 or lower brominated congeners, corresponding to photolytic debromination of Br9, were observed.

Table 3. Estimated Acceleration Factors and Half-Lives for the Photodegradation of Br10 to Br9

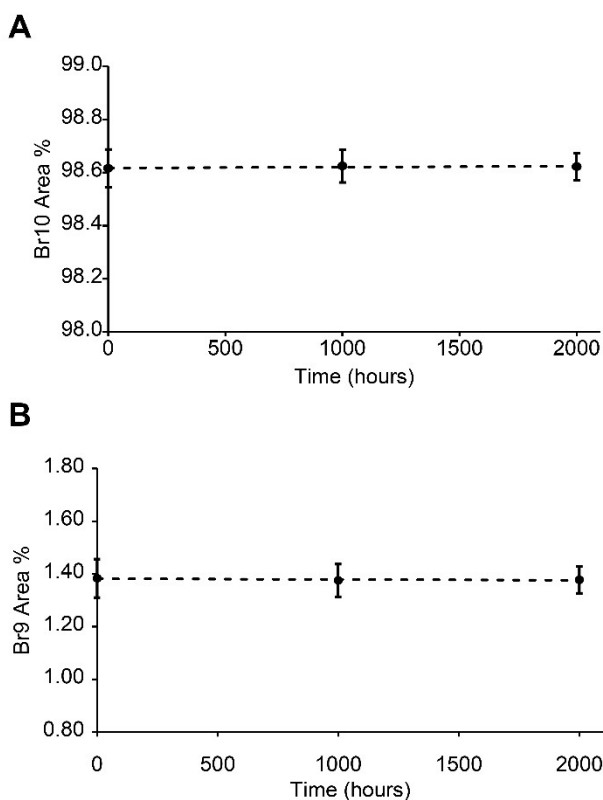
Region	Estimated Total Annual Dose (kJ/m ²)	Acceleration Factor	Estimated Half-life (years)
Western Europe/Canada	1700	8.4	660
Arizona/Florida	3200	4.5	355

Although we can attribute differences in the kinetics of degradation of Br10 to the differences in the two methods, both studies confirm EBP in HIPS compounds has a much longer half-life (5-6 orders of magnitude) than in dilute matrices, and the latter studies do not accurately reflect the photolytic performance of EBP in its intended use as a polymer additive. Furthermore, we can contrast these very long half-life estimates of EBP under solar irradiation in HIPS to those of DecaBDE in HIPS (*ca.* 51 days).¹⁰

For outdoor applications, it is an industry practice to use UV stabilizers to protect the entire material, including any polymer additive, from photolytic degradation. Compounds containing

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EBP respond well to UV stabilizers in a variety of resins.²⁶ To gauge the influence of UV stabilizers, we conducted a comparison with a proprietary combination of ultraviolet absorbers (UVAs) and hindered amine light stabilizers (HALS). A plot of the concentrations of Br10 and Br9 (Figure 5) showed that the EBP and Br9 concentrations remained flat over the 2000 hours.

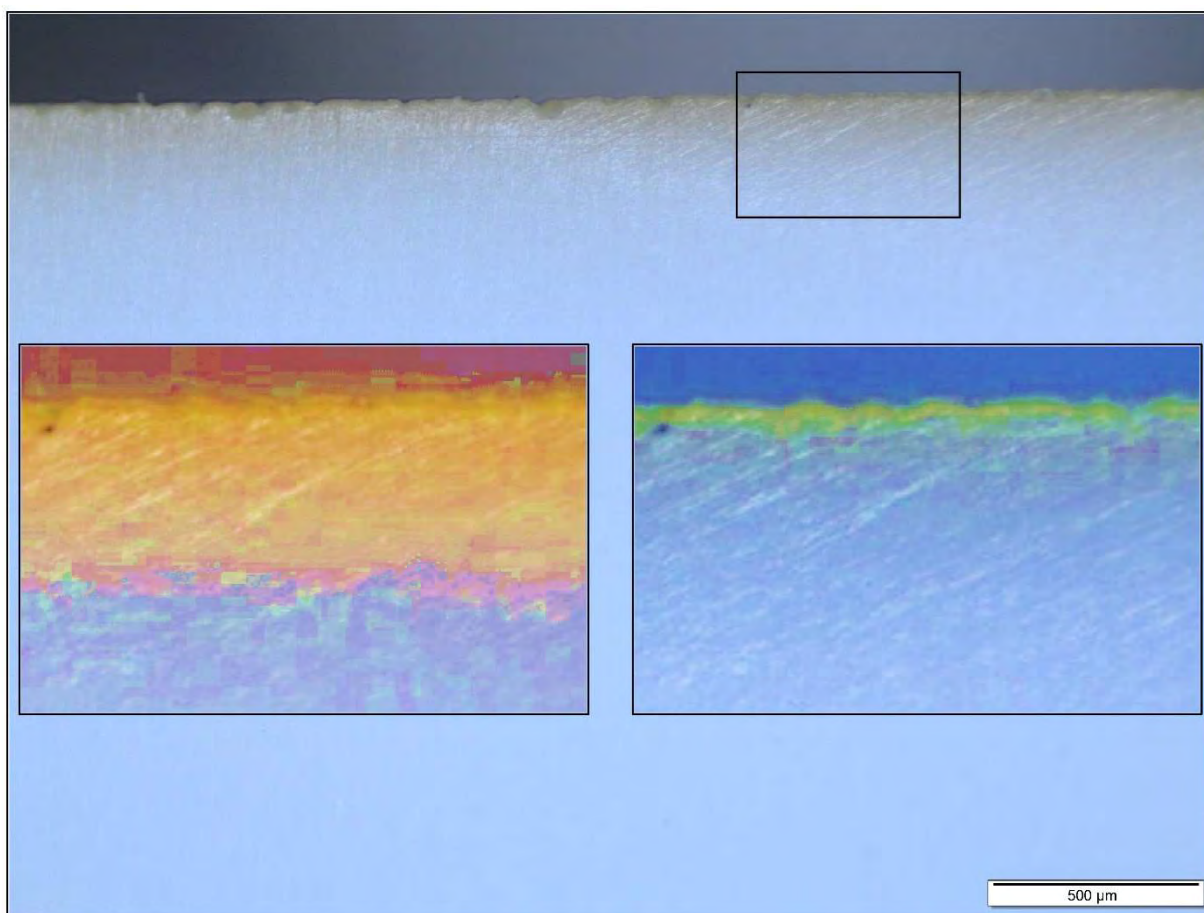


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Figure 5. HPLC/UV analysis shows no quantifiable change in the concentration of EBP (Br10) and Br9 after 2000 hours for UV-stabilized HIPS compounds.

What is the cause of the differences in the studies in solutions vs. solid compounds? One explanation is the formation of a surface skin that restricts the penetration of light. The overall depth of penetration did not appear to change with time in either study. For the ASTM D7869 study, the skin depth was ca. 20-25 microns, whereas the overall depth was ca. 130-160 microns (Figure 6). There is some subjectivity to the overall depth measurement since there is a gradient

194 of decreasing discoloration with increasing depth, but the bulk of the sample appeared to be
195 protected. Similar skin-level degradation was observed for accelerated UV degradation of a
196 polymeric bromine FR in polystyrene foam.¹²



197
198 **Figure 6.** Optical microscopy at 45× magnification showing discoloration of the EBP/HIPS
199 compound at 2000 hours at the surface. Overall, the bulk of the sample retained its initial color.
200 False color images (inset, 115× magnification) help to estimate overall discoloration depth (left)
201 and skin depth (right).

202 Previous studies with DecaBDE have shown that the FR can serve a dual role, first as a
203 chromophore, protecting deeper layers of PS films, and second as a source of Br radicals that can
204 promote H-abstraction and enhance oxidation.²⁷ However, the resin itself can oxidize and serve

as a chromophore with strong UV absorption to protect the underlying compound.²⁸ In our studies, the neat HIPS resin also showed a UV penetration depth similar to that of the compound containing EBP.

Khaled et al.²⁷ studied the photolysis of DecaBDE in polystyrene. These authors observed evidence for accelerated photooxidation of the resin by looking at the growth of peaks in the carbonyl region (1690 cm^{-1}) and hydroxyl region (3450 cm^{-1}). To determine if accelerated photooxidation was a concern in EBP/HIPS compounds, we conducted FTIR spectroscopic analysis of the sample surface after 1000 hours of photolysis. Figure 7 shows the spectra for the neat HIPS resin and the EBP/HIPS compound in the hydroxyl and carbonyl regions compared to the corresponding spectra of DecaBDE in polystyrene. The absorbance in each of these regions indicates clear photooxidation of HIPS in both neat resin and EBP/HIPS compound. However, unlike DecaBDE, no accelerated resin photooxidation is evident for the EBP compound.

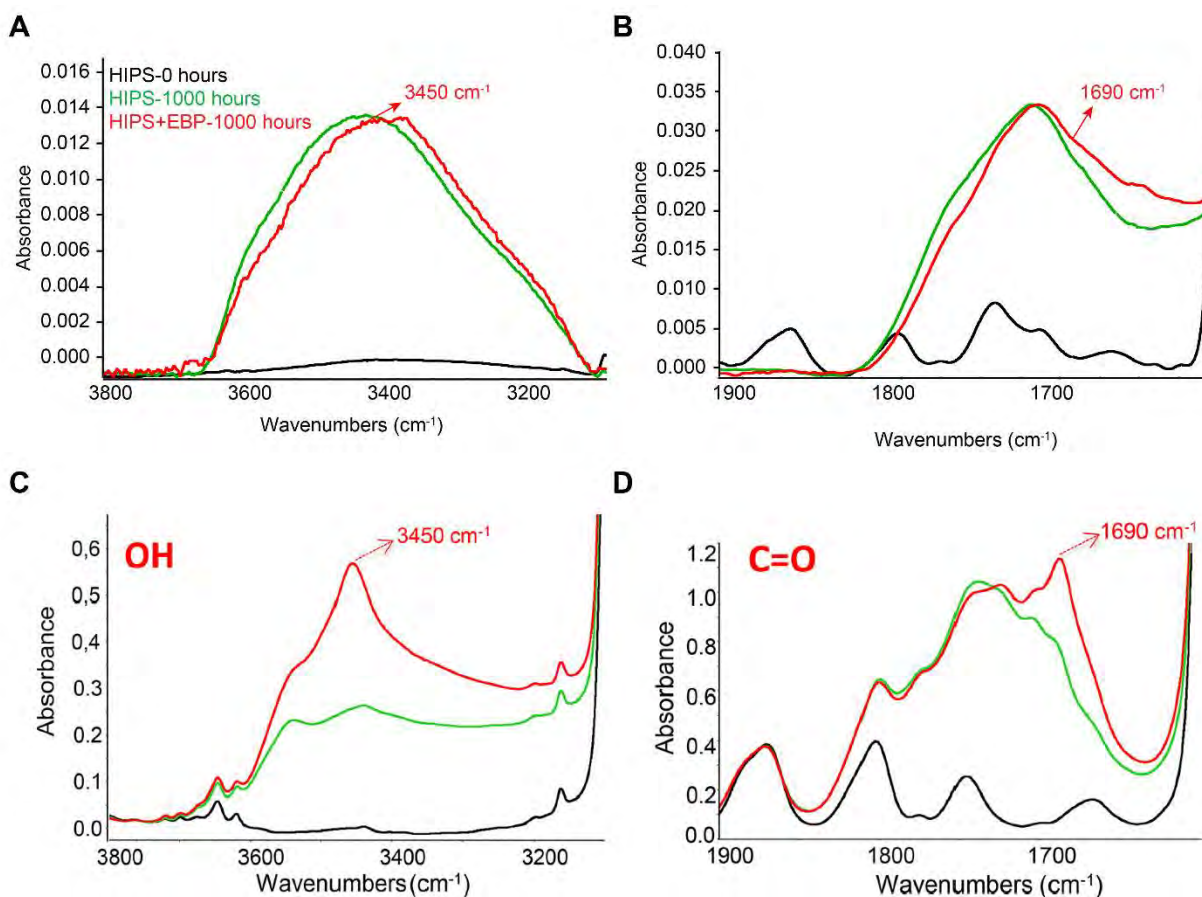


Figure 7. FTIR spectra of HIPS and the EBP/HIPS compound in the hydroxyl and carbonyl regions (top) after 1000 hours of weatherometry according to ASTM D7869. No peaks due to accelerated photooxidation were evident, as seen in the spectra for DecaBDE in polystyrene (bottom) at 1690 and 3450 cm^{-1} . The latter is reprinted with permission from Khaled et al.²⁷ Copyright 2018, American Chemical Society.

The photolytic behavior of DecaBDE and EBP, as well as other brominated FRs, has been studied in polystyrene previously by Torikai et al.,²⁹ who showed that the structural characteristics of the FRs affect their photostability. For wavelengths in the UV-A region (above approximately 300 nm) corresponding to solar irradiation, EBP was more stable than DecaBDE, as indicated by the unchanged carbonyl index of the EBP-containing resin at 1685 cm^{-1} .

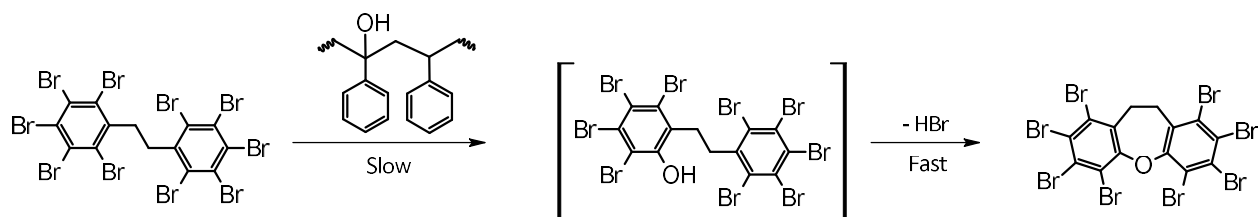
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Poor diffusion of oxygen into a solid matrix may also play a role, regardless of the penetration of UV light. Scott has shown that oxygen absorption and subsequent photooxidation of HIPS films vary with film thickness.³⁰

We also conducted extracted ion mass spectrometry (MS), looking at different molecular weights for species corresponding to photodegradation and photooxidation of EBP. Although no photodebromination from Br9 to Br8 or lower congeners was observed, a very low level of a species at a molecular weight consistent with the formula $C_{14}H_4Br_8O$ (Br8O) was observed. This result was surprising at first, based on literature reports that this would form after the photolytic loss of two bromines to Br8.^{15,18} These reports proposed a 7-membered ring structure with substitution of bromines by oxygen at the ortho positions. Our structural assignment of the Br8O species from an MS/MS experiment was consistent with the structural assignment in these reports. Furthermore, following the criteria described by Schymanski et al.³¹ for high-resolution MS, we ascribed a confidence level of 2 to this structure based on diagnostic analysis where no other structure fits the data.

Since no Br8 was observed in our studies, we explored alternative pathways where Br8 is not an intermediate in the formation of Br8O. The species is also present in very small amounts in the compound containing UV stabilizers as well as the compound after 336 hours of photolysis, which occurred without any water spray. Based on these observations, our current hypothesis is that Br8O formed not as a result of photooxidation or hydrolysis of EBP but rather slow nucleophilic substitution of EBP with hydroxyl groups of the photooxidized HIPS polymer³² at elevated surface temperatures during weatherometry (Scheme 1). The nucleophilic debromination of the second ring is fast, which is supported by previous results where a hydroxy species on the substituted FR molecule is not observed.¹⁸

Scheme 1. Nucleophilic Substitution of EBP with Hydroxyl Groups of Photooxidized Polystyrene giving the Br8O Species



At these low concentrations, we were not able to quantify Br8O to determine the rate of formation, although it is certain that it is *much slower* than the rate of photodegradation of EBP to Br9. We believe this substitution is unlikely to occur at appreciable rates under normal environmental conditions and more likely to be a consequence of the extreme conditions of the ASTM D7869 test.

Photolysis in PP. We also investigated the photolysis of EBP compounds in PP. Compared to formulations in HIPS, formulations in PP contain higher loadings (ca. 23%) of EBP to meet the UL-94 V-0 rating. We were only able to obtain recoveries of approximately 50% due to resin insolubility, but this was sufficient to identify degradation products. Unlike in HIPS, we observed no change in the EBP (Br10) to Br9 ratio, indicating no photolytic debromination under the ASTM D7869 conditions. We also detected no Br8O by MS.

The absence of EBP photodegradation and nucleophilic substitution products in PP may be explained by its lower ability to serve as a UV radiation trap and slower kinetics of photooxidation than that of polystyrene to transfer energy to accelerate photodegradation, e.g., in coresins.²⁸ The differences in photolytic behavior of EBP in PP and in HIPS corroborate the studies in solvents showing that matrix effects are important in the kinetics of degradation.

Furthermore, the photolytic behavior of EBP in PP may be contrasted with that of DecaBDE, which, while appearing to be structurally similar, does accelerate the photooxidation of PP as in HIPS.³³

Degradation and Nucleophilic Substitution of Lower Brominated Species. The absence of Br8 species in the solid matrix may not be unexpected based on studies in dilute media. Nadjia et al.¹⁵ estimated the half-life of the second photodegradation step, which corresponds to the disappearance of Br9 as shown by Chen, to be approximately $31\times$ longer (57.8 vs. 1.9 minutes) in THF.⁷ The rate of photolytic debromination of DecaBDE in dilute matrices has also been shown to decrease with each successive loss of bromine atoms.³⁴

In the present work, we observed no C₁₄H₅Br₇O (Br7O) or lower brominated congeners of Br8O. Their absence is also not surprising, as rates of nucleophilic bromine substitution are also expected to be suppressed with the successive loss of Br atoms in the oxygen-bridged molecules.³⁵

The Fate of Bromine and Brominated Compounds. As illustrated in Figure 8, for these HIPS and PP compounds, percent bromine determinations by the Schoeniger combustion (SC) method and NAA were not sensitive enough to indicate any change in bromine concentrations from 0 to 2000 hours of weatherometry. This result is not surprising since the amount of overall debromination due to photolysis and nucleophilic substitution is very low (ppm levels).

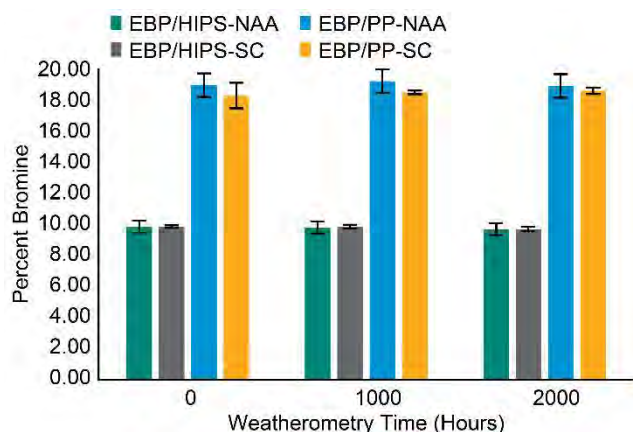


Figure 8. The bromine content in EBP/HIPS and EBP/PP compounds was determined by the Schöniger combustion (SC) method and neutron activation analysis (NAA). Within the reproducibility of the methods, no change in Br content was evident.

The samples retained their V-0 rating in the UL94 vertical flammability test, with $t_1 + t_2$ values adding up to under 10 seconds total for 5 measurements, readily meeting the ≤ 50 -second afterflame requirement specified in the standard.

Khaled et al.²⁷ showed one reaction pathway where bromine eliminated from the aromatic ring of a flame retardant reacts with the aromatic ring of polystyrene, forming a brominated polystyrene byproduct. Reactivity with the matrix was also observed in aliphatic solvents and polymers such as PP.³³ In both cases, the first step after debromination was proposed to be hydrogen abstraction to form HBr, which then further reacts with the bulk matrix.

In regard to the life-cycle analysis of EBP in application polymer formulation, the key takeaways from the present studies are as follows:

- Photolytic processes for EBP are significantly slower in plastic compounds, with half-lives that are orders of magnitude greater than in dilute solvent systems.

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- No photodegradation of EBP from Br9 to Br8, or further to lower brominated congeners of concern, was evident in HIPS.
- No photolytic debromination and no substitution of bromines were seen in PP compounds, exemplifying that matrix effects are as important in the solid state as they are in solution.
- The photodegradation rates and absence of accelerated resin photooxidation due to EBP as a polymer additive in HIPS can be contrasted with those for DecaBDE, which shows a much shorter half-life. A read-across comparison from DecaBDE to EBP would be misleading in risk assessment exercises.

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Notes

The authors declare the following competing financial interest(s): The authors are submitting this research work as employees of Albemarle Corporation, which markets EBP as SAYTEX® 8010 commercially.

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328 ABBREVIATIONS

329 Br10 $C_{14}H_4Br_{10}$, EBP, DBDPE

330 Br6 $C_{14}H_8Br_6$ isomers

331 Br7 $C_{14}H_7Br_7$ isomers

332 Br7O $C_{14}H_5Br_7O$ isomers

333 Br8 $C_{14}H_6Br_8$ isomers

334 Br8O $C_{14}H_6Br_8$ isomers

335 Br9 $C_{14}H_5Br_9$ isomers

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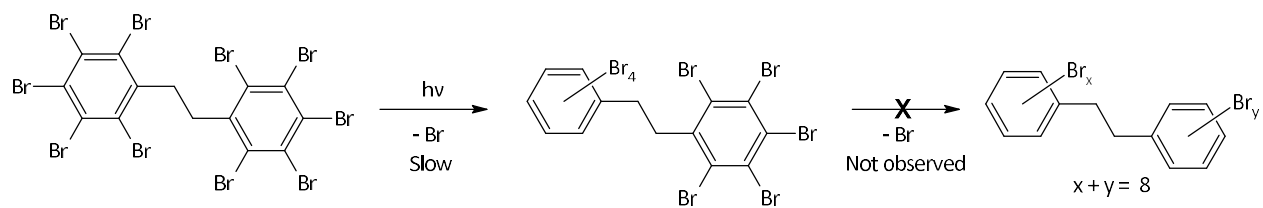
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438 GRAPHIC TOC

439



Supporting information for:

Is ethane-bis(pentabromophenyl) (EBP) an environmental concern? Assessing the impact of photolytic degradation in plastics

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Typical processing parameters to prepare test specimens for photolysis studies

High-impact polystyrene

Compounding

Temperatures, °C: 175 (Zone 1) – 175 (Zone 2) – 190 (Zone 3) – 215 (Zone 4) – 215 (Die)

Screw speed, rpm: 175

Feed rate, kg/hr: 10

Injection molding

Temperatures, °C: 200 (Nozzle) – 215 (Zone 1) – 215 (Zone 2) – 200 (Zone 3) – 60 (Mold)

Injection Pressure, MPa: 9.0

Hold Pressure, MPa: 8.5

Hold Time, seconds: 15

Cooling Time, seconds: 20

Polypropylene

Compounding

Temperatures, °C: 165 (Zone 1) – 165 (Zone 2) – 170 (Zone 3) – 200 (Zone 4) – 200 (Die)

Screw speed, rpm: 200

Feed rate, kg/hr: 10

Injection molding

Temperatures, °C: 200 (Nozzle) – 210 (Zone 1) – 210 (Zone 2) – 200 (Zone 3) – 60 (Mold)

Injection Pressure, MPa: 9.0

Hold Pressure, MPa: 8.0

Hold Time, seconds: 15

Cooling Time, seconds: 20

Appendix I

Analytical parameters for the 336-hour study

Column: 100 mm x 3 mm, 2.5 μ m Ace UltraCore PhenylHexyl

UV DAD detector: 220 nm, 4 nm bandwidth
Temperature: 60 °C
Flow: 1.0 mL/min
Injection volume: 4 μ L (with 5 sec THF needle rinses)
Mobile phase: A = Water
B = Methanol with 1% acetone

Analysis gradient:	Time (minutes)	%A	%B
	0	30	70
	18	5	95
	22	5	95

After each injection, a 1:1 acetonitrile:tetrahydrofuran mixture was used to rinse the column for 1 minute and equilibrated at 70% B for 6 minutes.

HPLC–MS instrument conditions:

Ionization mode: ESI, negative polarity
Peak width: 0.10 min
Acquisition mode: SIM

SIM parameters:

Group name	SIM ion	Gain	Fragmentor
Br	79.00	2.0	350
	81.00	2.0	350

Spray chamber settings:

Drying gas flow: 12 L/min.
Nebulizer pressure: 35 psig.
Drying gas temperature: 250 °C
Capillary voltage (negative): 3500 V

Appendix I

Analytical parameters for the 2000-hour study

Column: 100 mm x 3 mm, 2.5 μ m Ace UltraCore PhenylHexyl

UV DAD detector: 220 nm, 4 nm bandwidth

Temperature: 60 °C

Flow: 1.0 mL/min

Injection volume: 2 μ L (with 5 sec THF needle rinses)

Mobile phase: A = Water

B = Methanol

Analysis gradient:	Time (minutes)	%A	%B
	0	30	70
	18	5	95
	23	5	95

After each injection, 100% B was used to rinse the column for 3 minutes and equilibrated at 70% B for 6 minutes.

HPLC-MS instrument conditions:

Ionization mode: APCI, negative polarity

Acquisition mode: SCAN

Scan range: 100-1100 m/z

Spray chamber settings

Drying gas flow: 5 L/min.

Nebulizer pressure: 60 psig.

Drying gas temperature: 350 °C

Vaporizer temperature: 325 °C

Capillary voltage (negative): 3000 V

Corona current: 10 μ A

Two reference ions at m/z 112.9855 and m/z 1033.9881 [Agilent P/N G1969-85001] were used to correct the m/z of all ions, ensuring a mass error of less than five ppm during analysis.

LC calibration data and graphs for Br10

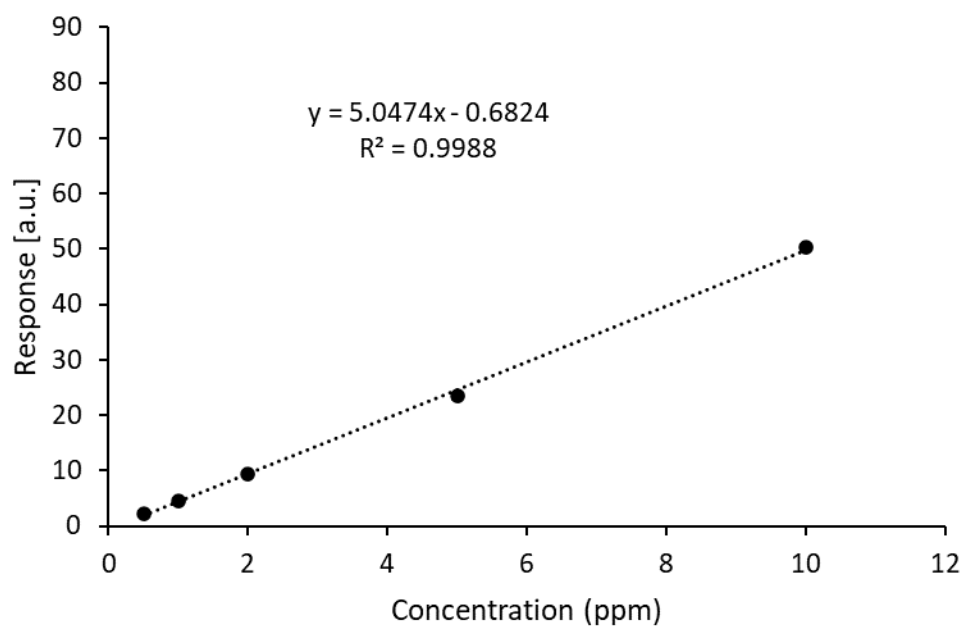


Figure S1. Calibration plot for Br10

Table S1. Calibration data for Br10

Concentration (ppm)	Intensity [a.u]	SD (n=3)
0.50	2.29	0.10
1.00	4.53	0.14
2.00	9.41	0.49
5.00	23.41	0.68
10.00	50.33	0.16

LC graphs and data for the 336-hour study in HIPS

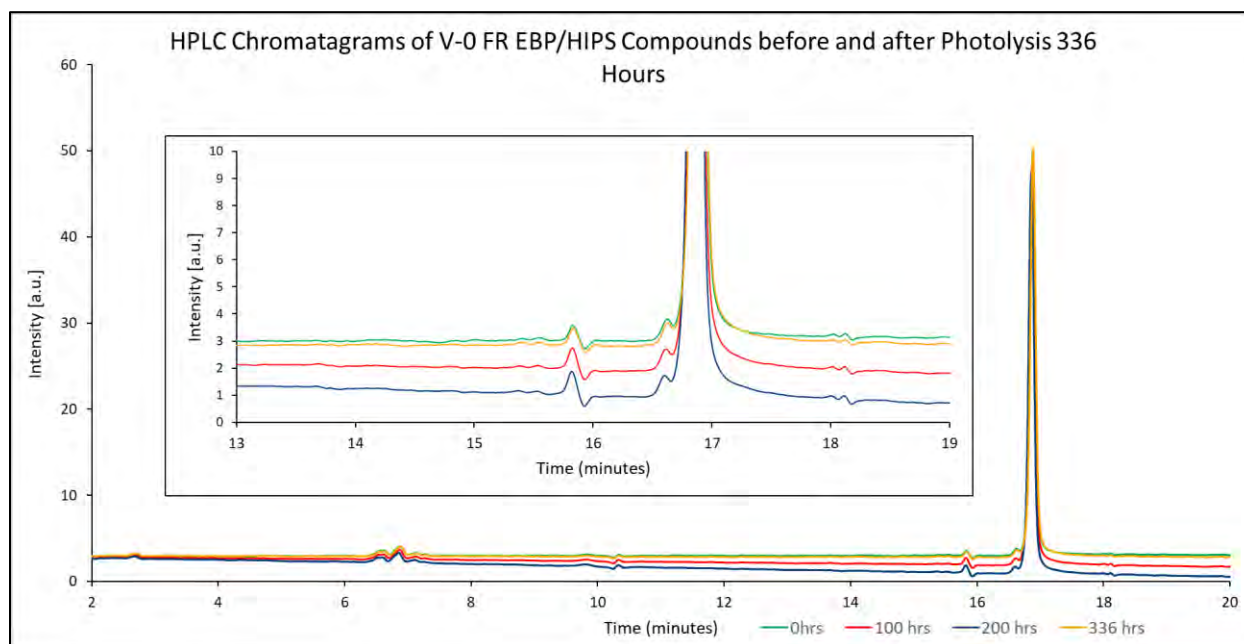


Figure S2. HPLC chromatograms of FR-HIPS compounds before photolysis and at 100, 200 and 336 hours of photolysis. The magnified region (inset) shows no Br8 congeners from photodegradation at ca. 100 ppb detection limit

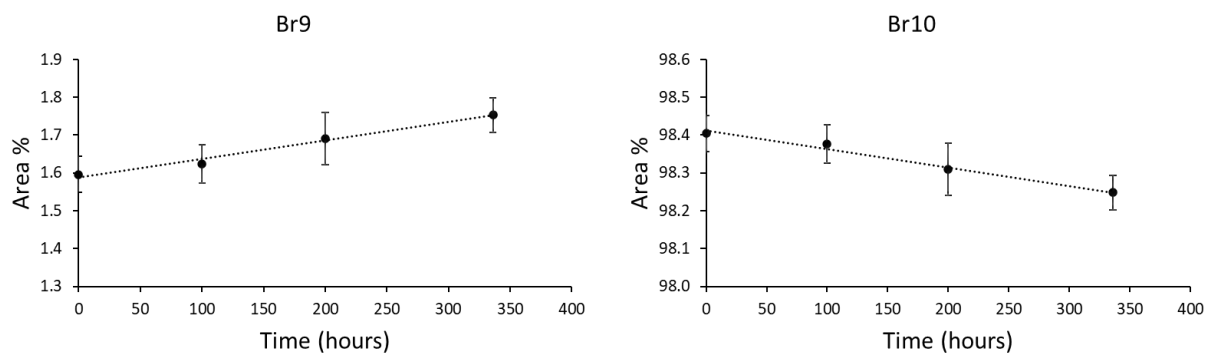


Figure S3. Plot for change in the amount of Br9 and Br10 in HIPS during 336 hours of UV exposure

Table S2. Data for the change in the amount of Br9 and Br10 in HIPS during 336 hours of UV exposure

UV Exposure Time (hrs)	Area %					
	Br9 (n=9)			Br10 (n=9)		
0	1.60	±	0.05	98.40	±	0.05
100	1.62	±	0.05	98.38	±	0.05
200	1.69	±	0.07	98.31	±	0.07
336	1.75	±	0.05	98.25	±	0.05

LC graphs and data for the 2000-hour study in HIPS

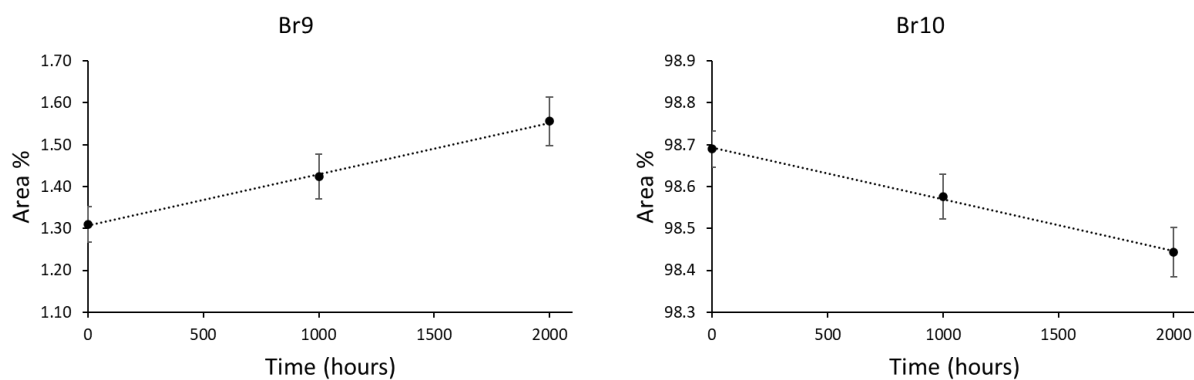


Figure S4. Plot for change in the amount of Br9 and Br10 in HIPS during 2000 hours of UV exposure

Table S3. Data for change in amount of Br9 and Br10 in HIPS during 2000 hours of UV exposure

UV Exposure Time (hrs)	Area %					
	Br9 (n=9)			Br10 (n=9)		
0	1.31	±	0.05	98.69	±	0.04
1000	1.42	±	0.05	98.58	±	0.05
2000 ^a	1.56	±	0.06	98.44	±	0.06

^a For 2000 hours n = 7

LC data and graphs for the 2000-hour study in HIPS with UV Stabilizers

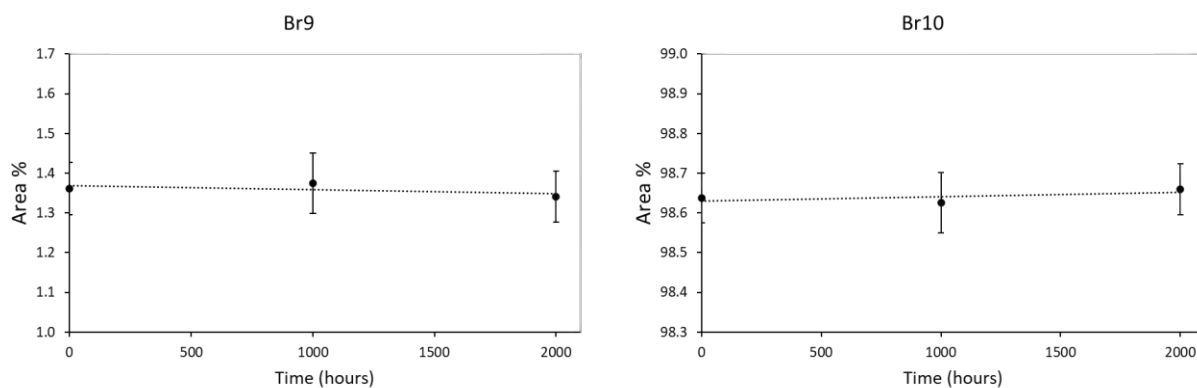
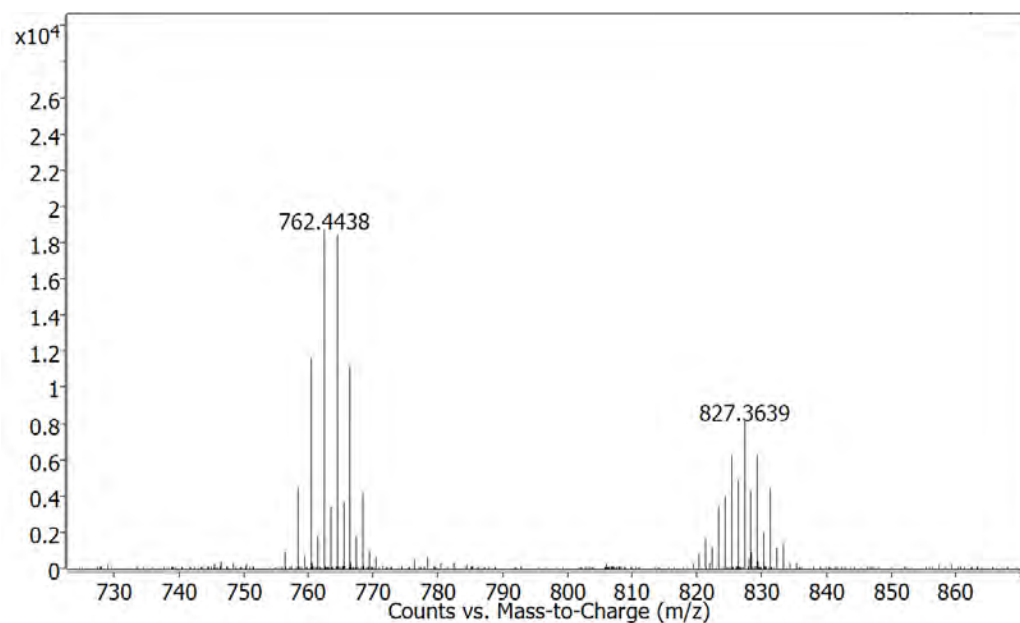
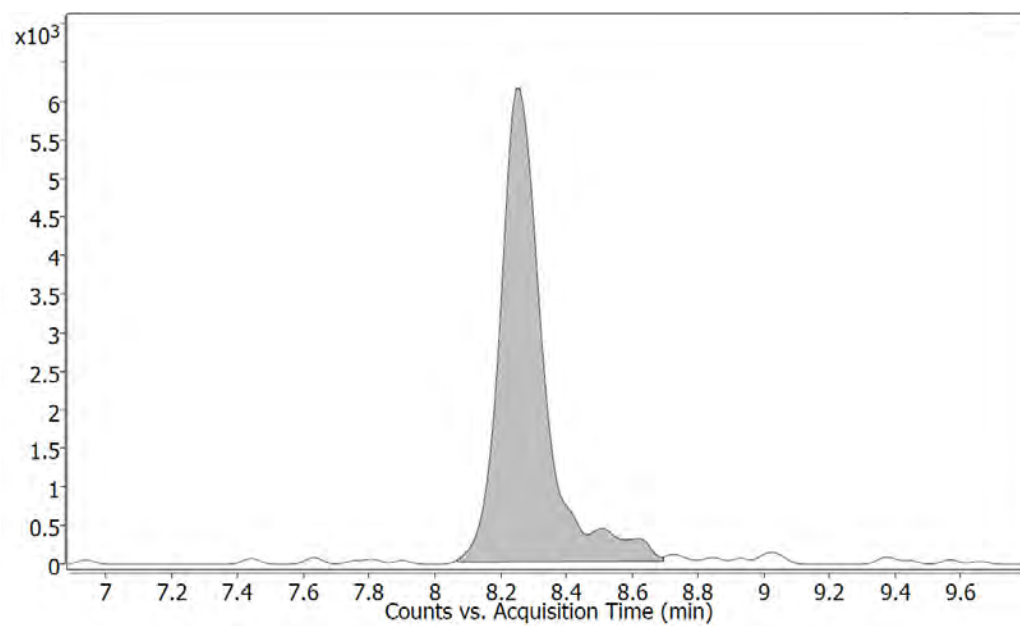


Figure S5. Plot for change in the amount of Br9 and Br10 in HIPS with UV stabilizers during 2000 hours of UV exposure.

Table S4. Data for the change in the amount of Br9 and Br10 in HIPS with UV stabilizers during 2000 hours of UV exposure.

UV Exposure Time (hrs)	Area %					
	Br9 (n=9)			Br10 (n=9)		
0	1.36	±	0.07	98.64	±	0.06
1000	1.37	±	0.08	98.63	±	0.08
2000	1.34	±	0.06	98.67	±	0.06

EIC of the Br8O species

**Figure S6.** Mass spectrum of Br8O.**Figure S7.** Extracted ion chromatogram for Br8O ($827.3639\ m/z$).

LC data and graphs for the 2000-hour study in PP

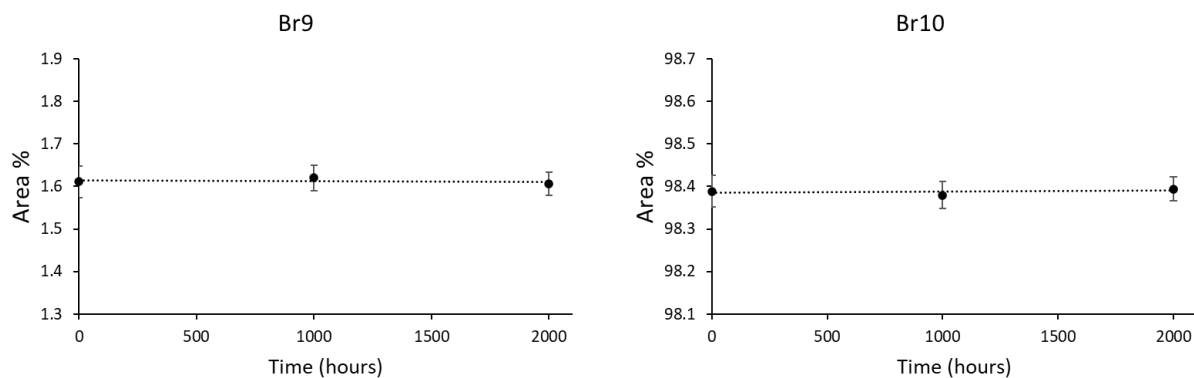


Figure S8. Plot for change in the amount of Br9 and Br10 in PP during 2000 hours of UV exposure.

Table S5. Data for the change in the amount of Br9 and Br10 in PP during 2000 hours of UV exposure.

UV Exposure Time (hrs)	Area %					
	Br9 (n=9)			Br10 (n=9)		
0	1.61	±	0.04	98.39	±	0.04
1000	1.62	±	0.03	98.38	±	0.03
2000	1.61	±	0.03	98.39	±	0.03

Appendix II

Evaluation of the Environment and Climate Change Canada Screening Risk Assessment and Risk Management of Decabromodiphenyl ethane (DBDPE)

Frank A.P.C. Gobas

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Summary

In 2019, Environment and Climate Change Canada (ECCC) concluded that decabromodiphenyl ethane (DBDPE, Chemical Abstracts Service (CAS) Registry Number 84852-53-9) meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999), i.e. it enters or may enter the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. In its screening assessment, ECCC relied heavily on information on the environmental behaviour and ecological risks of another organic flame retardant, i.e. decabromodiphenyl ether (decaBDE, CAS Registry Number 1163-19-5). ECCC concluded “*that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE (p. 32).*”, and that “*DBDPE may contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated (B)DPEs in the environment*”.

DecaBDE was considered to meet the criteria under paragraph 64(a), but not paragraph 64(b) of CEPA in screening risk assessments in 2006 and 2010 (Environment Canada 2006, 2010). In the screening assessment for DBDPE, ECCC argued that because decaBDE and DBDPE share structural similarities, they act in a similar manner and should therefore be regulated and managed in a similar manner. In their assessment, ECCC applied a method referred to as “read-across” where the characteristics of one substance (*decaBDE* in this case) are assumed to apply another substance (DBDPE).

The purpose of my report is to evaluate whether the rationale used by ECCC to conclude that decabromodiphenyl ethane meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999) is correct and whether a Board of Review is

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appropriate for achieving a correct risk assessment for DBDPE and substances with similar properties. For that reason, my investigation addresses the following questions:

- (i) Does DBDPE transform to lower brominated products in a manner similar to decaBDE?
- (ii) Is DecaBDE a good a read-across for the formation of DBDPE debromination products?
- (iii) Is there evidence to substantiate that debrominated DBDPE products enter the environment in a **quantity or concentration** that have or may have an immediate or long-term harmful effect?
- (iv) Does DBDPE contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products?
- (v) Is a Board of Review required to reach a correct conclusion regarding the risk of DPDBE to environmental and human health?

The evidence and insights I present in this report shows that DBDPE does not and cannot transform to lower brominated products in a manner similar to decaBDE and that DecaBDE is not a good a read-across for the formation of DBDPE debromination products. Furthermore, there is no credible evidence to substantiate that debrominated DBDPE products enter the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect. Also, DBDPE does not contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products. As ECCC concludes itself, the only lower brominated (B)DPEs that have the potential of being formed (albeit at extremely slow rates) are probably all baseline toxicants, which are among the least inherently toxic substances in nature. And among those substances, chemicals like DBDPE and some of its debromination products are even less inherently toxic because they cannot even cause baseline toxicity.

I have to conclude that a Board of Review is needed not only to reach a correct conclusion regarding the risk of DPDBE to environmental and human health, but also to ensure that other substances with similar properties and a good safety record are assessed correctly. This is because:

1. DBDPE, which is a substance with a long record of safe use and which has been subjected to many toxicological studies, is improperly considered to be toxic by ECCC in absence of any evidence of toxicity.

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2. ECCC struggles to make evidence-based decisions for DBDPE. Despite a thorough compilation of the results from many scientific studies that accompanies the assessment, ECCC relies on questionable theories and an inappropriate use of the precautionary principle in situations where there is no evidence of threats of serious or irreversible damage.
3. It is crucial for the Government of Canada to be credible in its assessment of chemicals, so it can maintain the confidence of Canada's population and stakeholders that is needed to develop effective policies that protect environment and human health.

This opinion concludes that ECCC's rationale that DBDPE meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999), i.e., "*that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE (p. 32).*", and that "*DBDPE may contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated (B)DPEs in the environment*" is seriously flawed and should be revisited to reach an accurate environmental assessment of DBDPE. A Board of Review is a logical step towards that.

Appendix II

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Appendix II

List of Acronyms

<u>Acronym</u>	<u>Description</u>
BDE	brominated diphenyl ether
BDPE	brominated diphenyl ethane
CEPA	Canadian Environmental Protection Act
d	day or days
DBDPE	decabromodiphenyl ethane
DecaBDE	decabromodiphenyl ether
ECCC	Environment and Climate Change Canada
EI	Electron ionization
FID	flame ionization detector
g	grams
GC	gas chromatography
GC-MS	gas chromatography / mass spectrometry
GC-ECD	gas chromatography – electron capture detection
heptaBDE	heptabromodiphenyl ether
hexaBDE	hexabromodiphenyl ether
HIPS	high-impact polystyrene
HPLC	high-performance liquid chromatography
K _{oa}	octanol-air partition coefficient
K _{ow}	octanol-water partition coefficient
L	litre
M	molarity, as the number of moles of a solute in 1 litre of solution
mg/kg	milligrams per kilogram
mL	millilitre
nonaBDE	nonabromodiphenyl ether
octaBDE	octabromodiphenyl ether
PBDE	polybrominated diphenyl ether
pentaBDE	pentabromodiphenyl ether
QSAR	quantitative structure-activity relationship
SIM	selected ion monitoring
THF	tetrahydrofuran
UK	United Kingdom
US	United States
UV	ultraviolet

Appendix II

1. Introduction

In May 2019, Environment and Climate Change Canada (ECCC), issued a screening assessment of the organic flame retardant decabromodiphenyl ethane (DBDPE: Chemical Abstracts Service Registry Number 84852-53-9) (ECCC 2019). The ECCC screening assessment for decabromodiphenyl ethane (DBDPE) (ECCC 2019) includes a thorough compilation and review of the scientific literature on DBDPE including study results contributed by the lead registrant. The ECCC screening assessment presents much information from many different sources (including academia, governments and industry) that concludes:

- (i) DBDPE is a persistent substance that is transformed in the environment very slowly.
- (ii) DBDPE is not considered to be bioaccumulative according to bioaccumulation criteria as set out in the Persistence and Bioaccumulation Regulations of CEPA.
- (iii) Currently available toxicological data show that DBDPE is not expected to exhibit toxic effects in the environment as concentrations of DBDPE in the environment up to the environment's solubility limits are not associated with observed toxicologically relevant effects.
- (iv) DBDPE itself does not pose a risk to the environment or human health. In fact, the highest doses tested in experimental animal studies, with no treatment related effects, are 1,000,000 to 10,000,000 times higher than the estimates of exposure to DBDPE from environmental media or products available to consumers in Canada.

However, ECCC also concluded that DBDPE meets the criteria under paragraph 64(a) of CEPA, i.e., it is entering or may enter the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity but does not meet the criteria under paragraph 64(b) of CEPA as it is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger to the environment on which life depends.

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The rationale provided for the conclusion is that “*that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE* (p. 32).”, and that “*DBDPE may contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated (B)DPEs in the environment*”.

Because there is no direct evidence that DBDPE transforms in the environment to form persistent, bioaccumulative and inherently toxic transformation DBDPE products, ECCC (2019) relies on study results for another brominated flame retardant, i.e. decabromodiphenyl ether (decaBDE) to arrive at this conclusion. DecaBDE was considered to meet the criteria under paragraph 64(a), but not paragraph 64(b) of CEPA in screening risk assessments in 2006 and 2010 (Environment Canada 2006, 2010). In the screening assessment for DBDPE, ECCC argued that, because decaBDE and DBDPE share structural similarities, they act in a similar manner and should therefore be regulated and managed in a similar manner.

The main purpose of my evaluation is to investigate whether this rationale is correct. Specifically, my investigation addresses the following questions:

1. Does DBDPE transform to lower brominated products in a manner similar to decaBDE?
2. Is DecaBDE a good a read-across for the formation of DBDPE debromination products?
3. Is there evidence to substantiate that debrominated DBDPE products enter the environment in a **quantity or concentration** that have or may have an immediate or long-term harmful effect?
4. Does DBDPE contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated (B)DPEs in the environment?
5. Is a Board of Review required to reach a correct conclusion regarding the risk of DPDBE to environmental and human health?

In this report, each of the questions is addressed in sections 2 to 6. Final conclusions are presented in section 7.

Appendix II

2. Does DBDPE transform to lower brominated products in a manner similar to decaBDE?

In Environment Canada (2010), a “*conceptual model of possible environmental transformation pathways for decaBDE*” is presented in Figure 3-2 and a “*summary of decaBDE transformation products observed in laboratory studies with some relevance to environmental settings*” is shown in Table 3-2. Of specific significance in Figure 3-2 is the ring-closure pathway leading to the possible formation of brominated dibenzofurans. This is because brominated dibenzofurans are substances that are widely recognized to have a very high inherent toxicity, similar to that of brominated dibenzo-p-dioxins (Van den Berg et al. 2013). The toxicological effects, in particular the thyroid hormone disruption and the neurobehavioral alterations observed in fish after exposure to low levels of decaBDE (Noyes et al. 2011, 2013), observed for decaBDE in laboratory experiments in fish are effects that are associated with halogenated dibenzo-p-dioxins and dibenzofurans. Hence, evidence points to the potential of decaBDE to produce brominated transformation products that can cause dioxin-like toxic effects.

The other pathway that is included in Figure 3-2 of Environment Canada (2010) is a successive debromination pathway for decaBDE. What is of specific significance here is that debromination of decaBDE can produce lower brominated diphenylethers that also exert a dioxin-like toxicity, albeit to a degree that is expected to be lower than that of brominated dibenzofuran transformation products because of structural dissimilarities between dioxins and diphenylethers. Substances like brominated dibenzo-p-dioxins, dibenzofurans and diphenylethers exert a dioxin-like toxicity and are among substances with the greatest known inherent toxicity.

However, the transformation pathways for decaBDE identified in Environment Canada (2010) do not apply or cannot occur for DBDPE. In other words, DBDPE cannot be transformed to products like brominated dibenzofurans and diphenylethers that have a dioxin-like toxicity. This is because the parent compound decaBDE is an ether and contains an oxygen atom in its structure. This makes it possible for decaBDE to be transformed to brominated dibenzofurans and lower brominated diphenylethers, which contain an oxygen atom in their main structures. DBDPE, however, is an ethane and does not contain oxygen and cannot form the brominated dibenzofurans and brominated dibenzo-p-dioxins through the ring-closure pathway outlined in Environment Canada (2010) that BDEs can. Also, for the same reason, it is impossible for DBDPE to form

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brominated diphenylethers, which also contain oxygen while DBDPE does not. In addition, BDPEs cannot form the “flat” rigid molecular configurations and dimensions that brominated dibenzofurans can and which are required to bind to the receptor associated with dioxin-like toxicity.

There are several papers that emphasize the differences in transformation pathways between DBDPE and decaBDE. For example, Kajiwara et al. (2008) observed no degradation of DBDPE in spiked high-impact polystyrene (HIPS) powder exposed to sunlight for 224 days, while the half-life of decaBDE in the same matrix was estimated at 51 days. Differences in apparent degradation rates between DBDPE and decaBDE were attributed to structural differences in ether (oxygen) bond vs. ethane bond.

Structural differences between DBDPE and decaBDE were also identified as the reason for differences in the degradation pathways during thermal decomposition of decaBDE and DBDPE in high-impact polystyrenes (Jakab et al. 2003). DBDPE decomposed mainly by the cleavage of the aliphatic C–C bonds resulting in the formation of bromotoluenes, whereas decaBDE decomposes by an intermolecular ring-closure pathway producing brominated dibenzofuran derivatives.

Further evidence that decaBDE and DBDPE do not share similar transformation pathways and toxicity profile comes from a recent study by Wang et al. (2019), who investigated thyroid disruption induced by decaBDE and DBDPE in rats. The study showed that “*Decreased total thyroxine (TT4), total T3 (TT3), and free T4 (FT4) were only observed in BDE-209 (decaBDE) group but not in DBDPE group.*” These observations indicate differences in toxicological pathways between decaBDE and DBDPE that are likely due to the formation of different transformation products. It needs to be stressed that the authors state that their findings suggested that both BDE-209 and DBDPE exposure could disrupt thyroid function. However, this occurred only at the highest dose level of 500 mg/kg body weight/day, which is a very high dose that is not normally encountered in the environment. The authors also conclude that “*DBDPE was found to be less toxic than BDE-209 (decaBDE)*”.

The lack of toxicity of DBDPE in the invertebrate *Daphnia magna* at concentrations of DBDPE in water that approach the maximum solubility limits of DBDPE (which are the highest possible

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concentrations in water that can be obtained and are orders of magnitude lower than concentrations in water in the environment) are consistent with this (Albemarle Europe 2019). The lack of any observed toxicity of DBDPE in organisms in water, sediment and soil at concentrations of DBDPE at or below the solubility of DBDPE further supports the inability for DBDPE to form brominated products that are toxic.

McKinney et al. (2011), who investigated oxidative and reductive debromination of DBDPE and decaBDE in an in-vitro test with liver microsomes from arctic marine feeding mammals (polar bear, beluga whale, ringed seal and laboratory rat), reported apparent depletion of DBDPE and decaBDE, but also concluded that simply debrominated metabolites were not observed. In general, metabolites were not detected that could account for the degree of DBDPE (or decaBDE) depletion.

In a comparative study of the uptake of decaBDE and DBDPE in rats, Wang et al. (2010, 2011) reported that *“Unlike (decaBDE), however, reductive debromination to lower brominated BDPes does not appear to be the primary metabolic mechanism of DBDPE in rats.”*

Environment Canada’s conclusion *“that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE (p. 32)”* is therefore not supported by the available evidence. DecaBDE is not a good model to anticipate environmentally relevant transformation products of DBDPE. Specifically, DBDPE cannot be transformed to form brominated dibenzofurans and diphenylethers, while decaBDE can. This point is very important in the risk assessment because brominated dibenzofurans and diphenylethers exert an unusually high inherent toxicity, which, judging from the study by McCarty and Mackay (1993), is approximately a million times higher than the baseline toxicity caused by BDPes. Because brominated dibenzofurans cannot be generated by DBDPE, DBDPE cannot be expected to exert toxicity similar to that of decaBDE.

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3. Is DecaBDE a good a read-across for the formation of DBDPE debromination products?

The Government of Canada (<https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/analogues-read-across-risk-assessment.html>) defines read-across “as one approach frequently used in the risk assessment of substances that lack information on their physical-chemical or toxicological properties, or their environmental fate. It involves using experimental or model data from structurally similar substances (analogues) to predict the behaviour of a substance being assessed (the target substance). The approach is based on the assumption that substances which are structurally similar will have reasonably similar physical-chemical properties, behave similarly, and elicit similar toxic effects.

Most commonly, read-across is used to fill data needs when particular information is lacking for the target substance.

In the read-across approach, information on a given property or endpoint for one or more analogues is used to predict (read-across) the property or endpoint for the target substance under assessment that is lacking this information. Different analogues may be selected for read-across to different properties of the same target substance. Read-across is most frequently used to estimate toxicity of a substance, but may also be used to provide estimates for bioaccumulation, degradation, physical-chemical properties, or to identify potential uses of the target substance.

The identification of suitable analogues for read-across of information requires a number of considerations including similarity in structural features, physical-chemical properties, and if available, reactivity, kinetics (absorption, distribution, metabolism, excretion), and information from other endpoints or routes.”

The Government of Canada specifically states that “Determining what constitutes sufficient similarity is important, as small changes in the structure of a substance may cause significant changes in behaviour.” And that “When selecting an analogue, consideration needs to be given to the specific property or endpoint for which it will be used. For example, a good analogue for degradation may not be an acceptable analogue for toxicity.”

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The Government of Canada states that “*There are several steps that are typically followed when selecting analogues for use in an assessment.*” They include:

- Search for potential analogues
- Compare structures
- Compare physical-chemical properties
- Consider metabolism / degradation pathways
- Compare toxicity, degradation and bioaccumulation
- Accept or reject analogue
- Apply read-across for accepted analogue
- Document uncertainties

However, in the case of DBDPE only one analogue was considered. Other analogues such as polybrominated biphenyls could have been considered as they are more closely related to DBDPE than ethers because of their lack of oxygen. Structures could have been subject to closer comparison as ethers and alkanes do not belong to the same chemical grouping. Physical-chemical properties of decaBDE and DBDPE differ considerably. For example, the log Kow of DBDPE is 9.89 (ECCC 2019) while the log Kow of decaBDE is 8.7 (Environment Canada 2010). This means that DBDPE is approximately 15 times more hydrophobic than decaBDE and hence can be expected to be less available for uptake and transformation reactions in aqueous environments than decaBDE. Metabolism and degradation pathways as well as toxicity profiles of DBDPE and decaBDE differ considerably as discussed in section 2. Also, uncertainties in the read-across are not detailed and documented.

When conducting a read-across, such as is done in the ECCC (2019) where decaBDE is used as a read-across for DBDPE, it is common practice to develop an appropriate rationale for the read-across. In their paper on “A strategy for structuring and reporting a read-across prediction of toxicity”, Schultz et al. (2015) state that: “*There are two major aspects of any read-across exercise, namely assessing similarity and uncertainty. While there can be an over-arching rationale for grouping organic substances based on molecular structure and chemical properties, these similarities alone are generally not sufficient to justify a read-across prediction. Further scientific justification is normally required to justify the chemical grouping, typically including considerations of bioavailability, metabolism and biological/mechanistic plausibility. Sources of*

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uncertainty include a variety of elements which are typically divided into two main issues: the uncertainty associated firstly with the similarity justification and secondly the completeness of the read-across argument.

This paper by Schultz et al. (2015) emphasises that, while there may appear to be an over-arching rationale for grouping organic substances based on molecular structure and chemical properties (as in the case of the Environment Canada assessment for DBDPE), these similarities alone are generally not sufficient to justify a read-across prediction. This is generally recognized and also by ECCC when their guidelines (<https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/analogues-read-across-risk-assessment.html>) state that “Determining what constitutes sufficient similarity is important, as small changes in the structure of a substance may cause significant changes in behaviour.” Further scientific justification is normally required to justify the chemical grouping, typically including considerations of bioavailability, metabolism and biological/mechanistic plausibility. The latter was not provided and/or not adequately considered.

In their report “A Class Approach to Hazard Assessment of Organohalogen Flame Retardants”, the National Academies of Sciences, Engineering and Medicine (NASEM 2019) investigates the application of a class approach to evaluating the hazard and risk of chemicals. The study used organohalogen flame retardants (OFRs), but not DBDPE, as an example. The report stressed the usefulness of a class approach as it is very difficult to assess chemicals on a chemical-by-chemical basis because of the large numbers of chemicals in commerce. Also, the report recognizes the fact that environmental exposure often involves multiple substances and that the combined effect is often of interest. The main output of the report is guidance and a general framework for how a class approach may be conducted. The main message related to an evaluation for a substance like DBDPE is to apply a tiered approach that initially relies on new approach methodologies (NAMs) that encompass computational modeling, in vitro assays in animal and human cells and tissues, and toxicity testing that uses alternative animal, species, such as zebrafish. The results of such studies can help to identify potential end points of interest and one or more chemicals in the subclass for targeted animal toxicity studies.

Given that ECCC (2019) tends to rely predominantly on results from published studies and has limited abilities to develop a research strategy that can determine whether substances can be

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grouped in classes, it is difficult for ECCC to implement the recommended framework for a class approach to risk assessment. However, there are some lines of investigation that Environment Canada could have been pursued with more energy. For example, the USEPA ToxCast program is an example of an approach that can provide information on whether DBDPE and decaBDE belong in the same class. Both chemicals have been tested in the ToxCast program. The ToxCast program found DBDPE to be inactive, while decaBDE was shown to be active in 2 out of 286 tests (<https://comptox.epa.gov/dashboard/>)

Computational modeling of (bio)transformation pathways could also have been conducted. Given the clear differences in compositional and structural formulas of DBDPE and decaBDE substances, such models would likely have shown that DBDPE cannot form the brominated dibenzofurans and diphenylethers which are the transformation products of decaBDE.

Given the current state of science, it is going to be difficult to apply a class approach to risk assessment. The report by NASEM concludes that *“At this stage, the committee does not find that biology can be used as a primary driver for subclass formation because the experimental data available are not adequate for doing so.”* Furthermore, the report concluded that *“Finally, the committee notes that forming classes and conducting read- across requires expertise that is not widely available.”* In my opinion, these general conclusions are justified given the current state of the science on this topic. The case of DBDPE and decaBDE discussed in this report illustrates that relatively small differences in structure can lead to substantial differences in chemical behaviour, including transformation pathways.

After evaluating the read-across conducted for DBDPE to common practices and guidance on read-across in the literature or by the report of the National Academies of Sciences, Engineering and Medicine or by the Government of Canada’s own guidance, I conclude that DecaBDE is not a good a read-across for DBDPE, in particular when it comes to the formation of DBDPE debromination products, which is the main reason for Environment Canada’s conclusion that DBDPE meets section 64(a) of CEPA.

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In my personal opinion, read-across approaches are subject to much uncertainty and, in the case of DBDPE, should be avoided altogether because much more other data is available that can be used to assess the hazards and risks of DBDPE in the environment.

4. Is there evidence to substantiate that debrominated DBDPE products enter the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect?

The screening risk assessment for DBDPE does not include evidence to substantiate that debrominated DBDPE products enter the environment in a **quantity or concentration** that have or may have an immediate or long-term harmful effect. The ECCC (2019) screening assessment for DBDPE concludes that “*current DBDPE concentrations in Canadian biota are unlikely to exceed minimum effects levels, within greater than 1000-fold margin of error*”. The screening risk assessment also concludes that conversion of DBDPE to transformation products of potential concern is “*very slow and subtle*”. This makes good sense because DBDPE is an extremely hydrophobic substance ($\log K_{ow} = 9.89$) with an extremely high organic carbon water partition coefficient ($\log K_{oc} = 8.58$) and an extremely high octanol-air partition coefficient ($\log K_{oa} = 14.45$). The physical- chemical properties of this substance causes DBDPE to strongly adsorb to sediments, soils and particulate matter in the environment. Only a minute fraction of DBDPE in environmental media is potentially available for diffusive and transformation processes involved in biological uptake or biotic or abiotic reactions. Indeed, dietary uptake in fish and rat is nearly absent, causing DBDPE to be selected as a “nonabsorbable benchmark”, where no absorption into the gastrointestinal tract was expected (Xiao et al. 2013). No absorption also means no biotransformation in the body of the animal. As a result, transformation of DBDPE in the natural environment, including photolysis, biodegradation and biotransformation, can be expected to be extremely slow.

It is inconceivable that the potentially “*very slow and subtle*” conversion of DBDPE to lower brominated BPDEs could produce concentrations or amounts of transformation products that would exceed minimum effects levels or would have any immediate or long-term harmful effect. The formation of lower brominated BPDEs in the environment, which requires a series of multiple very slow reactions, is therefore so extremely slow that it can only be considered hypothetical and

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inconsequential in the environment. This expectation is generally shared among regulatory agencies. For example, the Environment Agency in Great Britain concluded that: “Owing to DBDPE’s low water solubility, particle adsorption behaviour, as well as light attenuation by humic materials, photolysis in natural waters, soils, and biosolids is expected to be limited (Environment Agency 2007). ECHA (2022) concludes based on 6 studies that DBDPE is not biodegradable. Based on a study of the literature, the GreenScreen Assessment for Decabromodiphenyl concluded that there are no relevant environmental transformation products for this chemical. Also, a recent study by Albemarle (2022), which investigated the photolytic breakdown of DBDPE under artificial laboratory conditions (aimed at speeding up any photodegradation), further confirms these expectations as the estimated half-life time of DBDPE under normal environmental conditions was estimated from the experimental results to range between 350 and 660 years. Only trace amounts of nona-bromodiphenylethane were detected while other debromination products were not observed. Furthermore and consistent with the photolysis studies, biodegradation studies of DBDPE in aqueous media, which are cited in the screening assessment, show no or extremely slow microbial debromination rates of DBDPE under both aerobic and anaerobic conditions and the DBDPE debromination products nona-, octa-, hepta-, hexa-, and pentaBDPEs were not observed.

Given the very slow reaction rates, transformation products of DBDPEs are also unlikely to “build-up” in the environment because the rate of environmental removal or loss processes (i.e. burial or accretion) in sediments and soils (where the great majority of DBDPE ends up) are far greater than any potential formation rates of DBDPE transformation products.

It is important to note that the evidence that is used by ECCC to support the debromination theory is based on studies in artificial systems that (i) have no resemblance to those in the natural environment or industrial processes that DBDPEs may be subjected to; (ii) did not conclusively identify bromination transformation products because of a lack of suitable detection methods and/or required standards; and (iii) did not observe the bromination products of concern (i.e. brominated dibenzo-p-dioxins, brominated dibenzofurans, tetraBDE, pentaBDE and hexaBDE). One of the reasons for using artificial systems over natural systems to study the potential breakdown of DBDPE is that reaction rates of DBDPE are so extremely slow that they cannot be performed in any reasonable amount of time.

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Specifically, Nadjia et al. (2014) investigated the degradation of DBDPE in tetrahydrofuran solvent (THF) and in solid state phase under artificial ultraviolet–visible light using UV–visible spectroscopy. These experimental conditions are quite different and not representative of normal environmental conditions. The study used differential scanning calorimetry, thermogravimetry analysis and derivative thermogravimetry to monitor the biodegradation of DBDPE. These methods of detection can follow the loss of DBDPE, but not the transformation products that are formed. The degradation rate of DBDPE in THF was reported to be very fast. The authors suggest that the degradation of DBDPE involves the formation of successively less bromine-substituted congeners of DBDPE within the irradiation time. However, they did not report which brominated congeners were formed since their method of analysis was unable to do so. The authors concluded that *“Further research is required to understand the photolytic degradation pattern of DBDPE and to facilitate the design of remediation processes as well as help to predict their fate in the environment.”*

Wang et al. (2012) investigated the photolytic degradation of DBDPE in a variety of matrices (n-hexane, tetrahydrofuran, methanol/water, humic acid/water, and silica gel) by irradiation under ultraviolet light and in n-hexane under natural light. Most of the systems, with the possible exception of the humic/acid system, do not represent environmental conditions. Photolytic degradation of DBDPE occurred in all the matrixes investigated. The photolytic half-lives of DBDPE in the humic acid/water matrixes were much longer than those in the pure organic solvent matrixes. The authors suggested a likely quenching effect of humic acid on the DBDPE photodegradation. To identify debromination intermediates, the authors used full-scan mass spectra with EI mode. Because standards of debromination intermediates were not available, the authors could only identify BDPE intermediates within structural isomer groups according to GC–MS retention times and EI full-scan spectra. This method does not fully reveal the structures of the debromination products. Hence, there is considerable uncertainty about which brominated intermediates were actually formed. The authors reported the formation of nona-BDPEs and the subsequent decomposition of these congeners to octa- and hepta-BDPEs, but hexa-, penta- and tetra- BDPEs were not observed. The authors concluded that *“Further research is needed to understand the photolytic degradation pattern of DBDPE in the natural environment”*.

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In a preliminary study, which was not published in a peer reviewed journal, Kierkegaard et al. (2007) reported that technical DBDPE in n-hexane was photolytically degraded, producing two nona-BDPE congeners as well as a number of peaks tentatively identified as octa-brominated products. The authors suggested that DBDPE, like decaBDE, is subject to photolytic degradation, although they also stated that the relative susceptibility of the two chemicals has yet to be evaluated. The conditions in the experiment were not representative of environmental conditions. Also, the transformation products were insufficiently characterized and hepta-, hexa-, penta- and tetra-BDPEs were not observed.

In absence of evidence indicating the transformation of DBDPE to lower brominated BDEs in the environment, Environment Canada (2010) assumes that DBDPE is transformed in the environment in a fashion similar to that of decaBDE. However, there is no evidence of significant transformation of decaBDE to lower brominated BDEs in the environment. For example, Söderström et al. (2004) concluded that the lower brominated diphenyl ethers (e.g., BDE 47, 154 and 183) found in the environment probably originate mainly as emissions from the commercial pentabromodiphenyl ether and octabromodiphenyl ether mixtures rather than decaBDE photo transformation.

Rayne and Ikonomidou (2002) found that the reconstructed BDE congener patterns approximated those of the technical mixtures and concluded that the BDEs present in the region arose primarily from PeBDE and OBDE mixtures. Song et al. 2004 came to a similar conclusion, i.e. PBDE congener patterns found in the environment often resemble those of the PeBDE and OBDE commercial products. These observations make good sense as decaBDE is very persistent and hence does not breakdown very quickly to form transformation products. In addition, any debromination transformation products formed (e.g. nona-BDEs) are also very persistent and hence do not breakdown quickly either.

The transformation of decaBDE to form lower brominated BDEs in the environment, which requires a series of multiple very slow reactions is therefore extremely unlikely or slow. The transformation of decaBDE in the environment to potentially harmful lower brominated BDEs can therefore be considered insignificant. The corresponding transformation of DBDPE can be expected to be even slower than that of decaBDE. This is because DBDPE (log Kow is 9.89

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(Environment Canada 2019) is approximately 15 times more hydrophobic than decaBDE (log Kow is 8.7 (Environment Canada 2010)) and hence expected to be less available for degradation reactions in aqueous environments than decaBDE.

The only debromination of decaBDE of significance in the environment is the debromination observed in the intestinal tract of carp (Stapleton et al. 2004). This observation makes sense as the intestinal tract has the right chemical environment for reductive debromination to occur. However, the transformation reaction is very slow and only a very small fraction of the administered decaBDE (i.e. 0.4%) in the experiment appeared to be transformed to form penta- to octa BDEs. This mechanism has not been observed for DBDPE. Also, any uptake of DBDPE transformation products from the intestines into the body of the fish can be expected to be much slower than corresponding transformation products of decaBDE because the Kow of DBDPE transformation products are much greater than those of corresponding transformation products of decaBDE. This has indeed been observed. For example, Wang et al (2010) showed that in a comparative study of the uptake of decaBDE and DBDPE in rats, DBDPE was found in all tissues at concentrations that were a 1000 to 100,000 times lower than those of decaBDE.

ECCC recognizes that transformation of decaBDE to lower BDEs and BDFs “*has not been conclusively shown through monitoring studies to occur in the environment* (Environment Canada 2006)”. ECCC suggests that “*the process of environmental transformation may be very slow and subtle, and possibly may have relevance to a small fraction of the total decaBDE reservoir in the environment.*” Also, ECCC emphasizes that “*Evidence of transformation may be shielded by existing patterns of PBDEs in the environment which are dominated by congeners found in the commercial products.*”

It can be concluded that ECCC’s presumption that decaBDE is significantly transformed in the environment to form lower brominated BDEs is currently not supported by actual evidence. Hence, the presumed debromination of decaBDE cannot be used as credible evidence for the debromination of DBDPE. The only evidence of debromination of decaBDE that is environmentally relevant is the formation of lower brominated BDEs observed in the intestinal tract of fish. However, a dietary study in rats showed that reductive debromination of DBDPE to lower brominated BDPEs is not the primary metabolic mechanism of DBDPE in rats (Wang et al.

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2010). The evidence indicates that DBDPE is not converted in the intestines to lower BDPEs in a fashion that resembles that of decaBDE.

Another line of evidence that can be used to address the question whether debrominated DBDPE products enter the environment in a quantity or concentration that have or may have an immediate or long-term harmful effect comes from toxicity studies.

Toxicity studies in water, sediment, soil and in-vitro experiments show that effects of DBDPE are only recorded when the dosing concentrations exceeded (often greatly) solubility limits in the environment. Even the induction of enzyme levels in one molecular-level study with DBDPE (McKinney et al. 2011) emphasized in ECCC (2019), involved a solution above the solubility limit. In essence, this means that concentrations of DBDPE and its potential transformation products cannot reach levels in the environment that can have an immediate or long-term harmful effect. This is consistent with QSAR toxicity models for DBDPE, which were considered to be unreliable by ECCC due to exceedance of log Kow cut-offs, or the substance being poorly covered by the toxicity training sets (ECCC 2019). The log Kow cut-off presents some very useful (and well-established) information for the risk assessment of DBDPE that is consistent with and helps to explain the lack of toxicity of DBDPE observed in aquatic toxicity tests. In essence, the QSAR toxicity models say that DBDPE and its higher brominated transformation products cannot cause aquatic toxicity through a mode of toxic action referred to as narcosis or baseline toxicity because they are so insoluble in water that concentrations of these substances in the environment can never reach values that are high enough to reach or exceed effect levels. The log Kow cut-offs that ECCC is referring to is what is often referred to as the Ferguson cut-off (Kaiser 2012), named after Ferguson (1939) who first described the lack of toxicity for substances due to their solution properties (Abernethy and Mackay 1987). The reason that the training sets did not cover high Kow substances (like DBDPE) is that these high Kow substances are not toxic and cannot be used in correlations between log Kow and toxicity because there is no observed toxicity. The lack of toxicity of DBDPE at all possible dissolved concentrations of DBDPE in the environment is an unusual property for a chemical substance and makes it a relatively safe substance compared to substances that are able to cause toxicity.

In conclusion, while the transformation of DBDPE to lower brominated BDEs has been shown in organic solvents and some other artificial materials, it has not been shown to occur in the

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environment. This makes sense as DBDPE is extremely persistent, extremely insoluble in water and extremely sorptive to particulate matter, causing any potential debromination to be so extremely slow that it is virtually impossible to observe detectable or biologically significant concentrations. The scientific data currently available do therefore not support the conclusion that DBDPE or its potential debromination products enter or may enter the environment in a **quantity or concentration** that have or may have an immediate or long-term harmful effect. In fact, the data indicate that, as far as we know, all thermodynamically possible concentrations of DBDPE in the environment do not cause effects. Possible exceptions to this are spills of neat DBDPE.

5. Does DBDPE contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products?

The screening assessment of DBDPE (ECCC 2019) concludes that DBDPE is persistent, not bioaccumulative and that DBDPE itself is not inherently toxic and is probably a baseline toxicant and that aqueous-based exposures alone is not capable of exerting a lethal effect to organisms in aquatic environments. These are all correct conclusions in my view.

The virtual lack of dietary uptake of DBDPE observed in fish (Albemarle 2020) and rats (Wang et al. 2010) indicates that dietary exposures also are not capable of exerting a lethal effect in organisms.

Potential debromination products of DBDPE, like nona-bromodiphenylethane and octa-bromodiphenyl ethane possess similar properties of persistence, lack of bioaccumulation due to very low uptake rates and lack of inherent toxicity due to solubility cut-offs. Potential debromination products of DBDPE are also likely baseline toxicants. When referring to the inherent toxicity of baseline toxicants it is important to understand that, as far we know, baseline toxicity is the lowest possible inherent toxicity that a substance can exert. That is why they are referred to as **baseline** toxicants. In essence, all organic substances are expected to exert this basic or baseline toxicity unless they act in a special way through another mode of toxic action such as interactions with specific receptors (e.g. dioxin-like toxicity). Baseline toxicants are among the least inherently toxic substances in nature. And among those substances, chemicals like DBDPE and some of its debromination products are even less inherently toxic because they cannot even cause baseline toxicity.

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ECCC's apparent argument for why DBDPE is of concern is that debromination products of DBDPE, unlike DBDPE itself, can contribute significantly to the combined concentration of baseline toxicants (i.e. all other organic substances in nature) to cause or may cause immediate or long-term effects. This argument is incorrect. Concentrations of any possible DBDPE debromination products in the environment can be expected to dwarf concentrations of DBDPE itself due to its "*very slow and subtle*" release in the environment. If DBDPE is safe, as ECCC concludes, then debromination products of DBDPE are also safe.

6. Is a Board of Review required to reach a correct conclusion regarding the risk of DPDBE to environmental and human health?

It is puzzling to me that, given the ample available information on the environmental fate and effects of DBDPE, which is generally well documented in ECCC (2019), ECCC relies on guess-work to conclude that DBDPE meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999).

It is also puzzling to me that, after the Board of Review for Decamethylcyclopentasiloxane D5 (Environment Canada 2011), once again, a relatively well-studied substance with a long record of safe use and which has been subjected to many toxicological studies is considered to be toxic by ECCC in absence of any evidence of toxicity at all possible environmental concentrations. The process of chemical risk assessment in Canada is still subject to some major scientific shortcomings and errors. For that reason, I recommend that a Board of Review be established for DBDPE to re-evaluate the scientific process for the risk assessment of DBDPE and substances with properties like DBDPE.

It is crucial for the Government of Canada to be credible in its assessment of chemicals and maintain the confidence of Canada's population and stakeholders that is needed to develop effective policies that protect environment and human health. Because ECCC does not have the capacity to conduct research on the wide array of substances in commerce, it has to rely on all stakeholders to provide the information for risk assessments under the CEPA. If good quality studies from academia and industry are relegated to poor guess-work, stakeholders will lose

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confidence in current environmental policies and become less motivated to support good science-based policies through research. For this reason it is important to conduct a Board of Review in cases, like the one for DBDPE, where conclusions and evidence are very far apart.

7.0 Conclusions

This report concludes that the rationale for concluding that DBDPE meets the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999), i.e., “*that DBDPE is expected to transform to lower brominated products in a manner similar to decaBDE (p. 32).*”, and that “*DBDPE may contribute to the formation of persistent, bioaccumulative and inherently toxic transformation products, such as lower brominated (B)DPEs in the environment*” is seriously flawed and should be revisited to reach an accurate environmental assessment of DBDPE.

In the risk assessment of DBDPE, ECCC did not make an evidence-based decision. Instead of relying on the large amount of available scientific data compiled in the risk assessment (Environment and Climate Change Canada and Health Canada 2019), ECCC incorrectly uses questionable read-across theories and makes inappropriate use of the precautionary principle in situations where there is no evidence of threats of serious or irreversible damage. The weight of available evidence overwhelmingly supports that DBDPE is not a harmful substance but a product that can be safely used. Many years of safe use of DBDPE underscore this. As a scientist, it is puzzling that a risk assessment could end up so far off track.

A Board of Review is the best available option to correct the risk assessment of DBDPE and to revisit methods for conducting credible risk assessments of substances to protect environmental and human health.

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Wang F, Wang J, Dai J, Hu G, Wang J, Luo X, and Mai B. 2010. Comparative tissue distribution, biotransformation, and associated biological effects by decabromodiphenyl ethane and decabrominated diphenyl ether in male rats after a 90-Day oral exposure study. *Environ Sci Technol* 44(14):5655-5660, <https://pubs.acs.org/doi/abs/10.1021/es101158e>.

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Wang Yuwei , Tian Chen, Yanmin Sun, Xuezhen Zhao, Dan Zheng, Li Jing, Xianqing Zhou, Zhiwei Sun, Zhixiong Shi. 2019. A comparison of the thyroid disruption induced by decabrominated diphenyl ethers (BDE-209) and decabromodiphenyl ethane (DBDPE) in rats *Ecotoxicology and Environmental Safety*, Volume 174: 224–235. <https://www.sciencedirect.com/science/article/abs/pii/S0147651319302404>.

ONTARIO AGRICULTURAL COLLEGE
School of Environmental Sciences

July 13, 2022

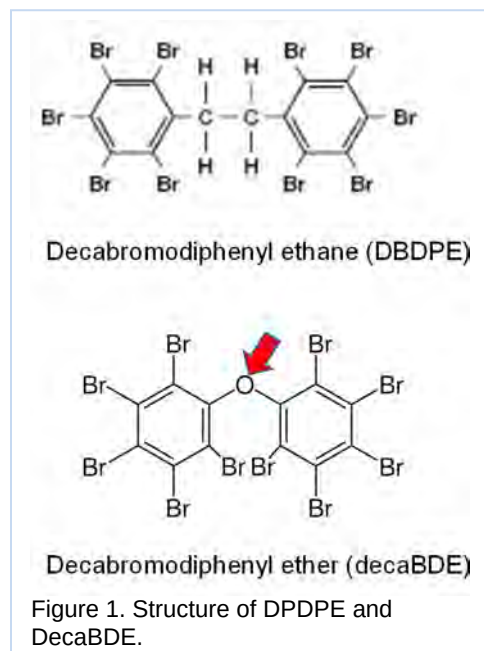
Re: Decabromodipheny ethane (DBDPE, (CAS Registry Number 84852-53-9)

I have been asked to review a report prepared by Professor Frank Gobas¹ and associated relevant literature on the environmental fate and photolysis of Decabromodipheny ethane (DBDPE) a flame retardant used in plastics, including wiring and other plastic products where there is a risk of the initiation and/or propagation of fires.

I am a University Professor Emeritus at the University of Guelph. I have more than 50 years of experience in research and teaching in environmental toxicology and have contributed to more than 460 scientific publications and reports in the fields of pesticides, environmental toxicology, and risk assessment. Relevant to the above issue, I was a member of the Review Board for D5 Siloxane for Environment Canada, 2010–2011²

I have read the report from Prof. Gobas and agree with his conclusion that ECCC³ incorrectly used read-across data on decabromodiphenyl ether (decaBDE) to extrapolate the potential for DBDPE to undergo photolysis from data and to form potentially toxic products, such as brominated furans. As pointed out in Prof. Gobas' report¹, the structure of these two chemicals is quite different in that DBDPE lacks the -O- moiety that is the basis for formation of furans (red arrow in Figure 1). It is for this reason that read-across from decaBDE to DBDPE is inappropriate. Therefore, there is no evidence to show that DBDPE breaks down in the environment and forms potentially toxic products in a similar way to decaBDE.

I also agree with Prof. Gobas' conclusion that DBDPE does not meet the criteria under paragraph 64(a) of the Canadian Environmental Protection Act (CEPA 1999)¹. Although it is persistent in the environment DBDPE is essentially unreactive and,

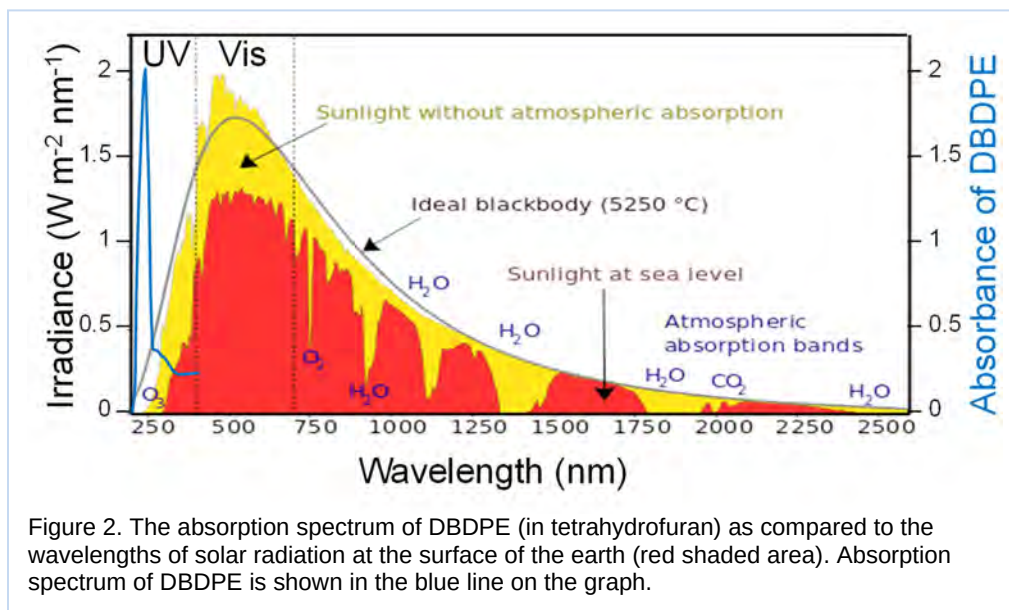


¹ Gobas, FAPC. 2022. Evaluation of the Environment and Climate Change Canada Screening Risk Assessment and Risk Management of Decabromodiphenyl ethane (DBDPE). Report. 23 p.

² Giesy JP, Solomon KR, Kacew S. 2011. Report of the Board of Review for Decamethylcyclopentasiloxane (Siloxane D5). Environment Canada, Ottawa, ON, Canada October 20, 2011. 83 p.

³ GC. 2022. Canada Gazette, Part I, Volume 156, Number 20: Prohibition of Certain Toxic Substances Regulations, 2022. 42 p. <https://gazette.gc.ca/rp-pr/p1/2022/2022-05-14/html/reg2-eng.html>.

even under photolysis, will not form potentially toxic substances. Further evidence in support of this conclusion that DPDPE is not expected to rapidly undergo photolysis to less-brominated and potentially toxic substances is indicated in a comparison of the absorption spectrum of DBDPE (from SI Fig 1 in Wang et al. 2012⁴) in Figure 2. Photolysis is also not expected in plastic products containing DBDPE and these plastics are usually formulated with UV absorbers to protect against environmental degradation of the plastic polymer.



Further, I agree with the conclusion of Prof. Gobas that DBDPE is of low toxicity to mammals and aquatic organisms¹. This is consistent with a lack of absorption in the gut of mammals and *de minimis* bioavailability in water because of low solubility.

Strong adsorption to soil and sediment is indicated by the log K_{OW} of DPDPE (9.89) and is confirmed by the log K_{OC} of 8.58¹. I agree that any DPDPE that might reach soil or surface water will adsorb strongly to particulate matter and sediments and this will further reduce the potential for exposure of biota in the environment. In addition, this adsorption will further minimise exposures to solar radiation and reduce photolytic breakdown even further.

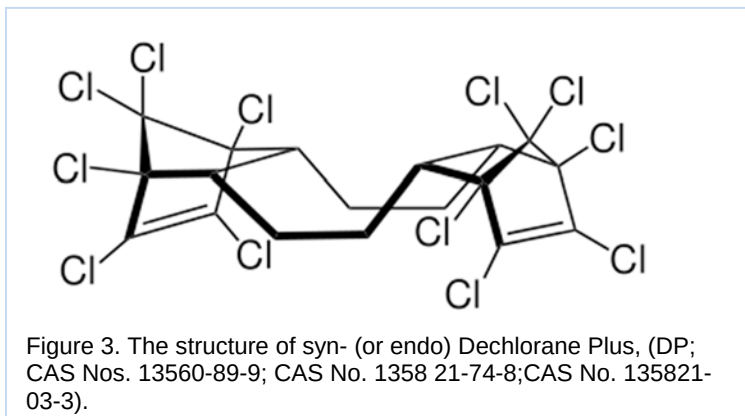
In short, there is no evidence to show that DBDPE and products containing this material present a risk to the environment and human health in Canada. In my opinion, a Board of Review would, in short order, reach the same conclusion. I would strongly urge ECCC to revisit their conclusions and avoid the resulting waste of resources that such a Board would entail.

As one further comment on the document in the Canada Gazette³, I do not understand

⁴ Wang, J. et al. 2012. Photolytic degradation of decabromodiphenyl ethane (DBDPE). Chemosphere 89, 844–849, <https://doi.org/10.1016/j.chemosphere.2012.05.006>.

the combined mention of DBDPE and Dechlorane plus (DP) in the same context of potential harm to human health and the environment. While I agree with the assessment

of the UNEP/POPS/POPRC⁵ regarding the potential risks of DP, this material (Figure 3) is structurally very different from DBDPE and there is strong evidence of exposure of humans and biota in the environment and of risks to humans and organisms in the environment. To lump these two compounds together makes no scientific sense.



Sincerely,

K S Solomon

Keith Solomon, PhD, Fellow ATS & Fellow SETAC
University Professor Emeritus,
ksolomon@uoguelph.ca



⁵ Report of the Persistent Organic Pollutants Review Committee on the work of its seventeenth meeting. UNEP/POPS/POPRC.17/13/Addendum.2.
<http://www.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC17/Overview/tabid/8900/Default.aspx>

July 12, 2022

Mr. Benjamin Gann
American Chemistry Council
North American Flame Retardant Alliance
700 2nd Street, NE
Washington, DC 20002

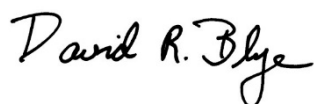
RE: Data Quality Evaluation – Study of Photodegradation of SAYTEX[®] 8010

Dear Mr. Gann:

Environmental Standards, Inc. (Environmental Standards) has been engaged by The American Chemistry Council (ACC) North American Flame Retardant Alliance (NAFRA) to evaluate the data quality associated with the study of "Photodegradation of SAYTEX[®] 8010". The enclosed report provides the details of Environmental Standards' review of the data quality associated with the study and analytical methodology.

Environmental Standards appreciates the opportunity to provide quality assurance services to the ACC NAFRA. If you have questions concerning this report, please contact me at (610) 935-5577 or by electronic mail listed below.

Sincerely,



David R. Blye, CEAC
Principal Chemist
DBlye@EnvStd.com

Environmental Standards, Inc.
1140 Valley Forge Road
Valley Forge, PA 19482- 0810
www.envstd.com

Enc.

DRB:nd

**DATA QUALITY EVALUATION
OF THE
STUDY OF PHOTODEGRADATION OF SAYTEX[®] 8010**

July 12, 2022

Prepared for:

**AMERICAN CHEMISTRY COUNCIL
NORTH AMERICAN FLAME RETARDANT ALLIANCE**
700 2nd Street, NE
Washington, DC 20002

Prepared by:

ENVIRONMENTAL STANDARDS, INC.
1140 Valley Forge Road
P.O. Box 810
Valley Forge, PA 19482-0810

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1.0 Introduction

The American Chemistry Council (ACC) North American Flame Retardant Alliance (NAFRA) requested an independent evaluation of the data quality associated with the study of Photodegradation of SAYTEX® 8010 conducted by Albermarle Corporation researchers. The timeframe to complete the evaluation dictated the review be conducted onsite at Albemarle's facility located in Baton Rouge, Louisiana. The onsite data quality evaluation was conducted by Principal Chemist, David R. Blye, CEAC, of Environmental Standards, Inc. (Environmental Standards) on July 6 and 7, 2022. Mr. Blye's professional profile is provided in Attachment 1.

Albermarle has conducted two studies on the photolytic degradation of flame retardant SAYTEX® 8010 that is comprised of ethane-bis(pentabromophenyl) (EBP), also referred to as decabromodiphenyl ethane (DBDPE). Previous studies by other researchers have focused on EBP degradation in dilute solvent matrices. Albermarle's studies look at the decomposition of EBP in high-impact polystyrene (HIPS) as reflective of real-world use of flame retardant in a polymer used for products like TVs, computers and office equipment. An initial 336-hour study was conducted where photolysis was conducted with accelerated UV exposure for 336 hours. This 336-hour study provided the mechanisms for developing the HIPS with flame retardant material to be exposed, sample preparation and analysis. However, the 336-hour study did not follow a standard reference method for controlled irradiance and water spray to mimic rain. The second study focused on flame retarded HIPS placed in a weatherometer over 2000 hours following the guidance in ASTM D7869. The 2000-hour study is the subject of this data quality review.

2.0 Brief on Environmental Standards

Environmental Standards is a specialty "niche" environmental consulting firm founded in 1987. Environmental Standards' specialty consulting offerings include environmental chemistry, geosciences, environmental data management, emergency response quality assurance oversight, and health and emergency support. The environmental chemistry services include data validation, laboratory audits, laboratory program development, environmental forensics, quality assurance program development and analytical method evaluation and development.

The Environmental Standards staff includes close to 40 consulting Chemists who have a total of more than 550 years of combined experience. Environmental Standards' chemistry staff includes B.S. through Ph.D. Chemists, six National Registry of Certified Chemists – Certified Environmental Analytical Chemists, and two American Society of Quality – Certified Quality Auditors.

Environmental Standards personnel have conducted numerous environmental studies covering a range of environmental issues including assessing PCBs in wire coating, PCBs in transformer fluids, hexavalent chromium in soils, and light gases in water. Environmental Standards chemists have also reviewed many US EPA analytical methods such as Method 1668 (PCB congeners), SW-846 Method 8327 (PFAS), Method 1633 (PFAS), Method 1621 (Available Organic Fluorine) and were co-authors of SW-846 Method 3060A (hexavalent chromium in soil) including the method validation studies for that method.

Environmental Standards experience is directly applicable to assessing the data quality associated with the photodegradation study for EBP.

3.0 Study Data Quality Evaluation

The ACC NAFRA requested that Environmental Standards provide an independent assessment of the EBP photodegradation study data quality to understand if the data quality was able to support the intended use and if the data was fit for purpose. The timeframe to complete the evaluation dictated the review be conducted onsite at Albemarle's facility located in Baton Rouge, Louisiana. The onsite data quality evaluation was conducted on July 6 and 7, 2022 by David R. Blye, CEAC, Principal Chemist with Environmental Standards.

The data quality evaluation focused on the following areas of the study:

- Study design,
- Preparation of HIPS material for use as test parts in the study,
- Photolysis of test parts,
- Sample preparation and extraction, and
- Sample analysis.

During the on-site evaluation at Albemarle, brief interviews were conducted with the study researchers and analysts to gain an insight of the personnel's understanding of the quality assurance and quality control procedures to ensure the study data were of defined quality. The following researchers were interviewed:

- Rajeev S. Mathur, Ph. D. – study lead scientist
- Bijay Banstola, Ph. D. – study research scientist
- Kelsey M. Lopez, Ph. D. – study research scientist.

Study Design

A summary of the photodegradation study, "Letter Report, February 14, 2022", prepared by Dr. Mathur and Dr. Banstola provides sufficient details on the study to allow an understanding of the scope and purpose. The study design allows for determination of photolytic degradation of EBP in HIPS under the guidance and conditions of ASTM D7869.

Preparation of HIPS material for use as Test Parts

An evaluation of the procedures used to produce and extrude the HIPS test parts indicate the process is controlled and documented. Procedures are in place to ensure little to no cross contamination of materials occurs in the equipment used. The HIPS test materials are representative of commercial products in use.

Photolysis of Test Parts

Test parts were photolyzed according to ASTM D7869 in an Atlas Ci4000 Weatherometer with a Xenon lamp at 340 nm. Water was introduced to the Weatherometer using water produced by a Culligan purification system. The parameters (irradiation duration, temperature, water spray sequences, rotation speed etc.) were programmed by the Atlas personnel, the manufacturer of the Weatherometer. The parameters such as temperature and light intensity are verified and calibrated on an annual basis. The Weatherometer is under a service contract with the manufacturer. The various conditions of the test part exposure are documented and defined.

Sample Preparation and Extraction

The study research scientist responsible for sample preparation and extraction provided an overview of the procedures used during the study. A demonstration of the extraction procedure was conducted. To extract the sample, it is first pulverized into a powder using liquid nitrogen and a cyromill. The portions of the test part that was not irradiated due to the mechanism

holding the part in the Weatherometer was cut off and removed prior to cyromilling the sample. About 15 – 20 mgs of powdered sample are extracted by sonication with HPLC grade tetrahydrofuran (THF). Volumetric glassware used to bring the extract solvent to final volume (100mL) were observed to be Class A to provide accurate volume determination. The analytical balance used to weight samples was properly calibrated. The sample extract to be used for instrumental analysis was filtered using a 0.2 um syringe filter. THF solvent blanks were prepared and filtered to provide control on external contamination. It is recommended that an inert matrix not containing any EBP also be taken through the entire preparation and extraction process to provide a control on potential contamination of the entire process. Examination of the study data did not indicate external EBP contamination was an issue. A HIPS without EBP was extracted during the onsite evaluation and analyzed with no detectable EDB indicating the system is free of contamination.

The preparation scheme did not make use of a surrogate compound to monitor individual sample extraction efficiency or use a matrix spike quality control sample where a sample matrix is fortified with EBP to monitor the extraction recovery on a batch preparation basis. To strengthen future studies, Albemarle scientists should consider incorporating these quality control tests into future analytical processes. Alternatively, use of a carbon-13 labeled isotope of EBP should be considered in future studies to allow use of isotope dilution analytical procedures.

To ensure the analytical preparation and extraction procedures adequately recover EBP from the polymer matrix, the EBP recovery study data were reviewed. Three samples contained EBP were extracted and analyzed in triplicate. The found concentrations were compared to the theoretical concentrations. These results show that EBP is extracted from the HIPS sample matrix at about 96 – 98% demonstrating efficient extraction procedures.

Sample Analysis

Sample extracts were analyzed by both HPLC with UV detection and high-resolution mass spectrometry (Q-TOFMS). Linear calibration of the instruments was demonstrated by running a five-concentration level curve with a correlation coefficient of >0.99 indicating good accuracy. Adequate detection sensitivity (~100 ppb) was determined by calculating the Limit of Detection (LOD) based on signal/noise of the low calibration point. Instrument calibration was conducted just prior to analysis of study samples. To strengthen future studies, calibration verification at the mid-point of the calibration curve should be considered if samples will be analyzed after 48- 72 hours from when the initial calibration is conducted.

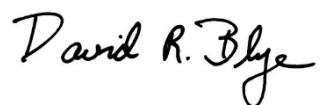
Each sample extract was generally injected three times to provide replicate measurements and to assess precision. Sample results used in quantitative evaluation by the researchers were based on the UV detector as it provided more precise replicate injection results.

A standard containing EBP and lower brominated congeners was analyzed by HPLC Q-TOFMS to allow qualitative identification of brominated congeners. Mass assignments for each bromine homolog from Br4 to Br10 allowed for searching of the sample data for presence of lower brominated congeners. Data was reviewed on the system used during the study and the absence of Br4 to Br8 congeners was confirmed.

4.0 Concluding Statement

An evaluation of the data quality associated with the 2000-hour EBP degradation study conducted by Albemarle indicates that the data and results are fit for purpose in interpreting photolytic degradation of EBP under the test conditions.

Report prepared by:



David R. Blye, CEAC
Principal Chemist

ENVIRONMENTAL STANDARDS, INC.
1140 Valley Forge Road
P.O. Box 810
Valley Forge, PA 19482
(610) 935-5577

Date: 7/12/2022



**ATTACHMENT 1
David R. Blye, CEAC
Professional Profile**





DAVID R. BLYE, CEAC
Principal Chemist
610.935.5577
dblye@envstd.com

FIELDS OF COMPETENCE

- Analytical and sampling quality assurance (QA) procedures
- Analytical database design
- Analytical data validation
- Analytical method development
- Data quality objective (DQO) development
- Environmental chemistry
- Environmental inorganic analysis methods
- Environmental organic analysis methods
- Field operations audits
- Laboratory audits
- Performance evaluation (PE) studies
- Quality Assurance Project Plan (QAPP) preparation and review
- Sampling and Analysis Plan (SAP) preparation and review

CREDENTIALS

B.S., Environmental Chemistry, SUNY College of Environmental Science and Forestry, Syracuse, New York, Cum Laude, 1983.

A.A.S., Ecology and Environmental Technology, Paul Smith's College of Arts and Science, Paul Smiths, New York, 1981.

CERTIFICATION

Certified Environmental Analytical Chemist (CEAC) - #2507 National Registry of Certified Chemists (NRCC), Washington, DC.

PROFESSIONAL AFFILIATIONS

American Chemical Society (Philadelphia Local Chapter)
American Institute of Chemists - Fellow (FAIC)
Water Environment Federation
Society of Environmental Toxicology and Chemistry
American Water Works Association Standard Methods Committee
Past President and Member of the Board of Directors of the National Registry of Certified Chemists (NRCC) (2009 – 2018)

SPECIALIZED TRAINING

US EPA TSCA Good Laboratory Practice Standards, 40 CFR Part 792, February 2005.
Target Software Fundamentals, Thermo LabSystems, February 2000.

SUMMARY OF EXPERIENCE

Mr. Blye has more than 36 years of diversified experience in the field of environmental chemistry; his experience includes field data collection and environmental sampling and the planning, development, and execution of field sampling and analytical projects. He specializes in the interpretation of organic and inorganic analysis data and the development of field procedures for the collection of representative groundwater, surface water, soil, air, and multi-media samples. He has generated site-specific sampling plans for more than 200 sites, including QAPPs for more than 47 state or federally supervised Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), and U.S. Department of Defense (DoD) sites.

Mr. Blye has extensive experience in US EPA organic and inorganic analytical methodology and analytical data validation. He has validated data analyzed according to 40 CFR Part 136 requirements (100-1600 Series), drinking water regulations (500 Series), RCRA requirements (SW-846), and CERCLA/SARA requirements (Contract Laboratory Program [CLP] Statements of Work [SOWs]) and has overseen the validation efforts of several hundred projects. He has developed internal and external training programs to teach data validation procedures according to US EPA requirements.

SUMMARY OF EXPERIENCE (Continued)

Mr. Blye also has extensive experience in auditing laboratory facilities to evaluate compliance with analytical protocols and QAPPs and to determine capabilities. He has audited more than 400 laboratories, 15 of which were participants in the CLP. He has also audited several laboratories in Canada, the United Kingdom, Europe, and Puerto Rico.

He is familiar with data management procedures for storing, retrieving, and reporting field and analytical data. He has worked closely with several laboratories to identify specifications for electronic delivery of analysis results to facilitate database management. He also has developed logic for both commercially available and project-specific electronic data verification tools.

Prior to joining Environmental Standards in 1992, Mr. Blye was Quality Assurance Manager for a nationally affiliated environmental consulting firm. He was responsible for directing laboratory subcontractor analytical services, special analytical projects, field and laboratory quality assurance/quality control (QA/QC) programs, and analytical data validation services. He managed and directed a staff of 11 QA Chemists whose primary duties were field QA procedure development, analytical data management, and analytical data validation.

KEY PROJECTS

- QA Program Manager for General Electric Company's Hudson River PCBs Superfund Site Sediment Sampling and Analysis Program (SSAP). This project is one of the nation's largest sediment remediation projects. The SSAP consists of collection and analysis of over 55,000 sediment samples to support the design of the dredging needed to remove polychlorinated biphenyl- (PCB-) contaminated sediment from the Upper Hudson River. The multi-year sediment sampling program began in the fall of 2002 and resumed during the summer and fall of 2003, 2004, and 2005. Mr. Blye assisted General Electric Company in developing the SSAP QAPP and implementation of the QA program including the rigorous PE sample program, electronic data verification, data validation and information management. Environmental Standards was responsible for the analytical data management tasks for the SSAP. Project-specific electronic data deliverables (EDDs) and a custom Oracle® platform database were implemented for the data management system. Mr. Blye directed
- Environmental Standards' activities associated with laboratory procurement for the SSAP analytical needs. He managed oversight of the nine contract laboratories used during the SSAP. Mr. Blye and Environmental Standards continue to support General Electric Company's efforts for the Baseline Monitoring Program, engineering design, and Remedial Action Monitoring Program (RAMP). During the Phase I dredging project conducted in 2009 and the Phase 2 dredging project conducted from 2010 to 2016, Mr. Blye served as the Quality Assurance Program Manager for the RAMP. The project is advancing to Operations, Maintenance and Monitoring (OMM), and Mr. Blye continues to support the long-term monitoring activities.
- Project Director for several site investigations focused on per- and polyfluoroalkyl substances (PFAS) in various matrices, including sites in New York, New Hampshire, Vermont, Michigan, New Jersey, West Virginia, and Ohio. Responsibilities include overseeing the data validation efforts, coordination with the various lead and data management consultants, and providing chemistry consulting on an as needed basis. Efforts include development of the protocols to review the PFAS data from multiple laboratories, as many of the analyses were performed by laboratory-specific techniques. Assisted in the improvement of the laboratory techniques and troubleshooting for unexpected results and new matrices. The projects have included aggressive schedules, training internal and external Chemists to review the data, and working with the project laboratories to resolve various errors.
- Conducted laboratory audits from 2011 to 2016 of seven commercial laboratories in the U.S and Canada performing PFOA analysis for a major chemical manufacturer.
- Served as part of the Project Team that critically reviewed and commented on SW-846 Method 8327 for preparation and analysis of PFAS analytes.
- Served as part of the Project Team that critically reviewed and commented on the Draft US EPA Method 1633 to support a consortium of industrial, law firm, and municipal clients. Draft US EPA Method 1633 provides procedures for the preparation of non-drinking water, solid, and tissue samples for per- and polyfluoroalkyl substances (PFAS) determination. The review

KEY PROJECTS (Continued)

and comment document was supplied to the US EPA Method Development Team. A significant number of technical comments were provided, and numerous inconsistencies were identified within the Draft US EPA Method 1633 document.

- Retained by the Delaware Estuary TMDL (Total Maximum Daily Load) Coalition (the Coalition) to provide expert analytical consulting services regarding the Delaware Estuary Stage 2 PCB TMDL. The Coalition is a group of 12 companies working with the Delaware River Basin Commission (DRBC) on scientific and technical issues associated with the PCB TMDLs. Mr. Blye represents the Coalition as a member of the Data Quality Subcommittee (DQSC) that assists the TMDL Technical Advisory Committee (TAC). In this capacity, Mr. Blye assisted in developing detailed analytical and sampling DQOs for collection and analysis of samples to be collected during the Stage 2 PCB TMDL study. Mr. Blye provided particular expertise in the analysis of samples according to draft US EPA Method 1668A - Chlorinated Biphenyl Congeners in Water, Soil, Sediment, and Tissue by HRGC/HRMS. Environmental Standards also assisted the Coalition members in procurement of analytical services to conduct the US EPA Method 1668A (modified for the DRBC) analysis for their point-source discharge outfalls, coordinating the analytical work, and validating the HRGC/HRMS congener analysis data. Environmental Standards also prepared the analytical deliverables according to DRBC requirements for submission by the Coalition members to the DRBC.
- Project Director for a major fuel oxygenates investigation in the Charnock Well Field, Santa Monica, California. Provided overall QA support to the client, a major oil company, and its lead consultant. Environmental Standards validated over 3,000 soil, groundwater, and vapor samples that were analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX), fuel oxygenates, and total petroleum hydrocarbons gasoline (TPHg). The project required extensive coordination with the client, client's outside counsel, the lead consultant, and multiple laboratories to identify and correct problems and to maintain consistency in reporting of data. The project was completed successfully under an extremely aggressive schedule. Environmental Standards assisted in data management aspects of the project, which included providing edited EDDs with the validated data to the lead consultant and preparing edited EDDs of the unvalidated data to make these data consistent with the validated data. Several customized reports were prepared to express the validated data. He also participated in preparation of the investigation report.
- Project Director for development of QAPPs for the two Enforceable Consent Orders (ECAs) to conduct Laboratory Scale Incineration Testing of Fluoropolymers and Fluorotelomers. The purpose of the overall testing program was to assess the potential for fluoropolymers and fluorotelomers to emit perfluorooctanoic acid (PFOA) during laboratory-scale combustion testing under conditions representative of typical municipal waste combustor operation in the United States. The QAPPs were required under the ECAs to comply with US EPA's Good Laboratory Practices (GLP) under Section 792 of the TSCA regulations and to be prepared in accordance with US EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5), marrying two distinct QA programs into one QAPP.
- Senior Chemist that directed the technical support to various private industrial clients and coalitions (the Utility Water Act Group, the Federal Water Quality Coalition, and National Association of Clean Water Agencies), as related to the proposed approval of US EPA Method 1668C (Chlorinated Biphenyl Congeners in Water, Soil, Sediment, Biosolids, and Tissue by HRGC/HRMS) in the *Code of Federal Regulations* (CFR). Support included meeting with US EPA to discuss concerns related to approval of the method and the generation of a detailed critique of the method, various inter-laboratory studies, peer review, and other supporting documentation. The critique was submitted to the docket by the various clients during the public comment period. The US EPA has currently deferred action on Method 1668C based on these submittals.
- Served as Project Director for Vinyl Chloride Producers (VCP) Group, which represented a total of 13 manufacturing locations. VCP Group required the services of a seasoned data validation expert for dioxin/furans by US EPA Method 1613B, as it needed to include alternative sample preparation and analytical technique variations. According to the method, the concentration of 2378-TCDF must be confirmed

KEY PROJECTS (Continued)

on a second, more polar GC column due to potential interferences with non-2378 TCDF-congeners on the commonly used GC columns. For the client's PCDF source using the GC column in the US EPA method analysis, the bias for other 2378-substituted PCDF-congeners can

also be high. For this project, the confirmation analysis was extended to all *tetra*- through *hexa*-CDD/F. The project included assisting with finalization of sampling and analytical QA guidance, training sessions for VCP Group participants, reviewing/validating initial laboratory QA qualification results to confirm adequate performance by laboratories participating in the project using an artificial QA/QC sample, and data validation for each individual group member.

- Reviewed a major chemical manufacturing company's in-house research laboratory's procedure for preparation and analysis for a PFAS in treated and untreated article-of-commerce samples; this review was part of the overall effort by the company to address the increasing number of independent studies on the toxicity and environmental occurrence of PFAS. Reviewed the resulting data under a very "tight" schedule to allow its presentation at a public forum. All of the article-of-commerce samples were extracted, and the resulting supernatants were analyzed for PFAS using a high-performance liquid chromatography tandem mass spectrometry (HPLC MS/MS) technique. The data were presented in the form of an Analyst's logbook that included sample analysis instrument raw data, standard and QC raw data, and notes documenting the procedures performed. Corrected the miscalculated values and identified both qualitative and quantitative issues that impacted the data. The client expressed appreciation of Environmental Standards' help and flexibility with the data analysis and recognized Environmental Standards' capabilities relative to the quality of the work and working within stringent project schedules. Served as Project Manager as part of the company's ongoing consent order-driven groundwater investigation to determine if there had been any impact on human health and the environment resulting from releases of PFAS into the environment; evaluated contracted research laboratory's QA/QC procedures and data extraction technique and HPLC MS/MS analytical

method for regulatory and data review purposes. Made several recommendations to make the data more consistent with the QA/QC and deliverable requirements for US EPA methods using similar technology. Provided oversight of the critical third-party review of the HPLC MS/MS analytical method.

- Project Director for Region I corrective action program (CAP) RCRA Facility Investigation (RFI) for an aerospace manufacturing facility in Connecticut. The project required assisting the client in the identification and selection of two qualified laboratories to provide an estimated \$7M in analytical services over the duration of the RCRA RFI. Developed an analytical services Request for Proposal (RFP), reviewed the bidders' proposals, interviewed the qualified candidates, and provided award recommendations to the client. Directed the preparation of project-specific Appendix IX analytical standard operating procedures (SOPs) to ensure data comparability for SW-846 methods between the two contracted laboratories. Prepared data validation SOPs for validation of the Appendix IX analytical data. Directed field audits of two primary engineering/environmental consultants to provide the client with an indication of the consultants' field QC procedures. Directed QC oversight of the initial soil-gas study investigation, including auditing the subcontractor soil-gas analysis laboratory. Directed validation activities for initial soil boring program and ICM study consisting of approximately 550 Appendix IX volatile and semivolatile organic sample analyses, 300 Appendix IX metals sample analyses, 60 dioxin/dibenzofuran sample analyses, 60 Appendix IX pesticide/PCB sample analyses, and 17 complete Appendix IX sample analyses. Prepared the Data Collection Quality Assurance Plan for the RFI. Validation activities required direct editing of the project database via remote-access software applications. SQL statements have been prepared to assist in transfer of data from unqualified to qualified state. Analytical data for approximately 1,000 soil, groundwater, surface water, and sediment samples were validated during the remainder of the Phase I RFI. A comprehensive Data Quality Assessment report that summarized all QA/QC oversight, auditing, and validation activities was prepared at the conclusion of the Phase I RFI.
- Laboratory Audit Team leader responsible for auditing six laboratories on the East Coast that participated in a Fortune 100 client laboratory

KEY PROJECTS (Continued)

program. Audits were conducted to satisfy the client's laboratory certification program requirements.

- Project Director responsible for providing QA support to the corporate remediation group of a Fortune 10 client; provides budget oversight, technical direction, and staff management for all projects for this client. Environmental Standards is this client's preferred consultant to provide data validation, data management, and QAPP preparation services.
- Laboratory Audit Team Leader responsible for auditing five laboratories in the Midwest under consideration for selection as a primary Tier I analytical supplier for an automotive manufacturer. Responsible for coordinating audit report production and providing senior technical review.
- Evaluated the impact of VOC contamination originating from a National Priority List (NPL) site on 25 residential wells in the vicinity of the site. Assisted in design engineering, installation, and monitoring point-of-entry treatment systems selected as contaminant remediation.
- Performed analytical data validation for numerous site investigations to determine analytical data outliers and data quality/usability.
- Prepared, documented, and implemented QAPPs for numerous state and federally led site investigations (CERCLA, RCRA, ECRA, DoD, USATHAMA, and NEESA).
- Evaluated the validity of analytical data collected for use in the Hazard Ranking Score for selection of a Pennsylvania site for the NPL. The primary issue concerned the use of soil-gas analyses performed using a field-portable GC.
- Interpreted volatile organic analytical data to identify the existence or potential existence of biological degradation of volatile compounds for several Pennsylvania and New Jersey site investigations.
- Laboratory Audit Team member responsible for auditing five United Kingdom laboratories under evaluation by two Fortune 100 clients.
- Directed analytical subcontract services (in excess of \$2.5M annually) for a major environmental consulting firm. Responsible for all contracting, price negotiations, and performance audits.
- Developed a field methanol extraction procedure for soil samples (in 1987) to yield a more accurate collection of VOC data and to assist in defining background conditions prior to the start-up of site remediation. The methanol extract was analyzed following the CLP medium-level volatile protocol. This technique has now become a preferred sampling procedure for VOCs (SW-846 Method 5035).
- Developed field soil-gas survey procedures to monitor for VOCs using both organic vapor analyzers and portable GCs. Managed several soil-gas surveys for clients as a means to inexpensively evaluate site background conditions and to cost-effectively implement traditional investigation methods.
- Prepared a QAPP for a large multi-national company to specify QA/QC requirements during the development of an Environmental Impact Statement (EIS) in Spain. A United Kingdom-based laboratory was audited, and procedures were developed for the laboratory to conform to US EPA analytical procedures. The successful completion of the analytical program required significant coordination with the Project Team and laboratory.
- Prepared a QAPP for a large multi-national company to specify QA/QC requirements for a field investigation conducted in support of a Feasibility Study at a PCB chemical manufacturing facility in Wales, United Kingdom. Specific analytical requirements were developed to allow the United Kingdom-based laboratory to comply closely with US EPA analytical procedures.
- Developed analytical requirements for the analysis of propylene glycol, ethanol, and glycerine in support of a stack emission test sampling program for a major tobacco processing company.
- Provided sampling and analytical oversight services to an insurance adjuster relative to contaminant remediation of tenant property due to a major high-rise fire in Philadelphia, Pennsylvania. Fire soot was found to be contaminated with dioxins and PCBs.

KEY PROJECTS (Continued)

- Developed a strict groundwater, surface water, and soil monitoring and analytical program to comply with a New Jersey State Administrative Consent Order for a major chemical manufacturer. Over 125 groundwater samples were collected on an annual basis and monitored for various VOCs, total phenols, and cumene. Sampling and analytical programs were developed to collect data necessary for a multi-discipline project team to assess potential risk at the site and to develop remedial measures.
- Provided “turnkey” analytical services for a large chemical manufacturer according to state permit conditions during the installation of a deep injection well at a phenol/acetone production plant. The analytical data subsequently indicated phenol to be present at a depth of approximately 3,000 feet. The client was identified by the state regulatory agency as the potentially responsible party for the contamination. Reviewed and validated the complex organic and inorganic data collected from the injection well formation fluids for use by various technical experts and attorneys; provided expertise in the analysis of environmental samples for use in the litigation.
- Provided analytical data validation services and litigation support to a West Virginia law firm. The law firm’s client was charged with criminal felony by the U.S. Attorney General for alleged illegal disposal of a RCRA hazardous waste. Reviewed the extraction procedure (EP) toxicity analysis data generated by the state of West Virginia for adherence to proper protocol and evaluated the sample-collection procedures used.

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Synopsis
Decabromodiphenyl Ethane (DBDPE) and Dechlorane Plus
(DP) in the Canadian Marketplace

Environment and Climate Change Canada conducted a
third party socio-economic study completed,
25 January 2020

Appendix V

Background

Final screening assessments for DBDPE and DP were published in May 2019 and concluded that these two substances are harmful to the environment as set out in paragraph 64 (a) of CEPA 1999. Therefore, the Minister of the Environment and the Minister of Health propose to add them to Schedule 1 of CEPA 1999. The Government of Canada is proposing measures to reduce the concentrations of DBDPE and DP in the Canadian environment to the greatest extent practicable, considering social, economic and technical matters, by managing their anthropogenic releases from all industrial sectors and activities. The Government to Canada is proposing to amend the *Prohibition of Certain Toxic Substances Regulations, 2012* to prohibit the manufacture, import, use, sale and offer for sale of DBDPE and DP, as well as products and manufactured items containing them.

This summary was drawn from an ECCC funded contract to gather technical and socio-economic data and information on Decabromodiphenyl ethane (DBDPE) and Dechlorane plus (DP) in the Canadian marketplace. The information contained in the report was comprised of publically available information and information acquired through industry engagement. The resulting analysis and recommendation are those of the independent consultant. The information contained in the study will however be considered in the development of appropriate risk management measures and the Regulatory Impact Analysis Statement (RIAS).

Use Patterns for DBDPE and DP

According to submissions made under section 71 of CEPA¹ and submissions under the New Substance Notifications Regulations, (Ministerial Conditions 13228 and 16260)^{2,3}, DBDPE is used in Canada as a flame retardant in: plastic and rubber materials such as thermoplastic or thermoset parts and coatings (for use in polymer resins and polymer plastics); electrical and electronics including appliances and wire and cable coatings for the telecommunications industry; automobiles (including airbag textiles), aircraft, and other forms of transportation, adhesives and sealants, appliances; and basic organic chemical manufacturing.

Overall, it is estimated that 100 – 500 tonnes of DBDPE are currently used in domestic manufacturing activities. Base on currently available information: ~55% of the total is used in manufacturing wire and cable products, ~24% in automotive manufacturing activities, ~10% in the production of other Electric and Electronic Equipment (E&E) products particularly electrical enclosures/power boxes, and ~10% in industrial adhesives, with <0.3% used in manufacturing industrial rubber products.

Approximately 500 – 1500 tonnes of DBDPE are were imported into Canada in 2018 with ~25% imported as a raw material for manufacturing purposes, and ~75% imported in resins, manufactured

¹ Canada 2013. Dept. of the Environment. Canadian Environmental Protection Act, 1999: Notice with respect to certain organic flame retardant substances [PDF]. Canada Gazette, Part I, vol. 147, no. 13, p. 613-633.

² Canada. 2004. Dept. of the Environment. Ministerial Condition No. 13228. Canada Gazette I 138(40):2645-2646. [accessed 2004 Oct]

³ Canada. 2011. Dept. of the Environment. Ministerial Condition No. 16260 [PDF]. Canada Gazette I 145(20):1513-1515. May 14, 2011.

Appendix V

articles and finished products. Imported electrical and electronic products including wire and cable products are responsible for the majority (68%) of DBDPE imports. Imported DBDPE in transportation equipment primarily functions as a flame retardant in wire and cable components, and other E&E components of finished vehicles. Of the 100 – 500 tonnes of DBDPE imported as a raw material, the majority is compounded into resins that are subsequently used to manufacture wire and cable products, wire connection products and electrical enclosures. Approximately 100 – 500 tonnes of DBDPE is exported per year, primarily in wire and cable products and transportation equipment.

DP is a low volume product for Canada. Uses of DP in domestic manufacturing activities (wire and cable manufacturing and transportation equipment manufacturing) were estimated to total 10 – 100 tonnes, with 10 – 50 tonnes imported primarily in finished vehicles, and 10 – 50 tonnes exported in wire and cable products, finished vehicles and aerospace products.

Lifecycle

Releases during the compounding of DBDPE into resins in Canada are expected to be low for direct releases to air, water, and land, based on total imports of 100 – 500 tonnes of DBDPE powder for compounding into resins in 2018. Total releases from all facilities using resins already compounded with DBDPE or DP (e.g. wire and cable manufacturers) are also estimated to be low for DBDPE and for DP. Some year-to-year off-site transfers for recycling or disposal may occur. Releases of DBDPE and DP during product service life are expected. Releases from products available to consumers are expected to be low, geographically dispersed, and spread out over the duration of the service life and end-of-life stages. Many products containing DBDPE are still disposed of in landfills although the portion being recycled is growing.

DBDPE and DP have low solubility in water and low volatility. They are expected to partition predominantly to dust, soil and sediment when released to the environment.

Profile of key industry sectors

Key sectors using DBDPE and DP in domestic manufacturing are the wire and cable sector, and the transportation equipment sector. The demand for flame retardants such as DBDPE and DP tends to track with GDP. When activity and spending in the construction, infrastructure, and transportation equipment sectors increases, then demand for DBDPE/DP increases as this is where the products containing these flame retardants are used. Demand in the wire and cable sector is heavily influenced by new construction particularly on non-residential buildings, such as factories, utilities, power plants, communication lines, office buildings and other non-residential buildings, which demand large quantities of power, communications infrastructure and building wire and cable. Consequently, as construction activity increases, demand for wire and cable products grows. Key downstream customer sectors for these wire and cable products include power transmission and distribution (submarine and land), Energy resources (Oil & Gas, Mining and Renewables), Transportation (Road, Rail, Air, Sea) and Building (Commercial, Residential and Data Centers).

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DBDPE and DP are used as flame retardants in numerous parts and components used in the transportation equipment-manufacturing sector. These include uses in automobiles and light duty vehicles (covered by NAICS 33611), Heavy Duty Trucks and Engines (NAICS 33612), and Aircraft Manufacturing (NAICS 33641). The automotive manufacturing industry is concentrated in what is referred to as the 'Great Lakes automotive manufacturing cluster'. Canada is one of the world's top 10 producers of light vehicles. Five global OEMs assemble an aggregate total, of more than 2 million vehicles at their Canadian plants each year. In addition, there are nearly 700 parts suppliers that supply the OEMs. As one of Canada's largest manufacturing sectors it plays a key role in Canada's economy. DBDPE and DP are also used in Aerospace Products and Parts Manufacturing (NAICS 33641).

Substitutes/Alternatives

Flame retardants are used in many products to meet fire safety standards. Broad-market standards such as the Canadian Standards Association (CSA) and Underwriter's Laboratories (UL) dictate certain levels of flame retardancy of finished wires and cables, and other types of products. Currently, these standards are broadly achieved through the addition of chemical flame retardants into the polymeric compounds. Certain alternative flame retardants to DBDPE and DP have been assessed. According to a number of stakeholders, at this time, effective fully tested alternatives are not currently known for many critical applications.

In general, the addition of any substance into a polymeric material represents a contaminant to the polymer, and negatively affects one or more of the polymer's properties, especially at high loading levels typical of flame retardants. Achieving the mandated level of flame retardancy requires trade-offs with the performance of the polymeric material, and can result in polymeric materials that do not meet the performance required by certain product standards, in some cases, or can result in polymeric materials that are very difficult to extrude into the required form. Examples of such trade-offs are basic tensile strength properties, crack resistance, resistance to crush or impact and the long-term insulation resistance.

Potential Benefits/Risks of the Proposed Risk Management Strategy

Flame retardants by design must be highly stable and resistant to breakdown to be effective in their end use applications over extended periods of time. Consequently, the potential alternatives would also be expected to be very stable compounds and likely to be persistent e.g. refer to the hazard summary table in the US EPA assessment of alternatives (US EPA 2014). Since the persistence of DBDPE and DP was one of the key concerns raised in the screening assessments of both chemicals, the fact that alternatives with similar chemical composition / properties are also highly likely to be persistent compounds is an important consideration when assessing the potential impact of the risk management strategy (RMS).⁴

It is important to weigh any potential benefits associated with reduced releases of DBDPE/DP with potential negative consequences associated with the use of alternatives. It is possible that alternatives could be developed in the future with time for appropriate R&D, testing and re-certification of products.

⁴ Obviously, persistence it is not the only property that should be considered, as inherent toxicity and bioaccumulation properties must also be taken into account in any comparative alternatives assessment, but the fact that most alternative flame retardants will also likely be persistent compounds should be recognized.

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In this regard, assessment of risks and benefits of the proposed RMS cannot be based solely on reducing releases of DBDPE and DP but must take into account the likelihood that alternatives once identified will have significantly preferable environmental and health profiles.

Appendix VI

SAYTEX 8010 (CASRN 84852-53-9): Analytical Chemistry, Pharmacology, and Toxicology Studies

Albemarle Corporation, Charlotte, NC. January 23, 2020.

Study	Testing Laboratory	Date of Final Report
Rat acute oral toxicity	Pharmakon	1988
Saytex 8010: an evaluation of inherent biodegradability using the CONCAWE test	Wildlife International	2010
Guinea pig skin sensitization	MPI Research	2003
¹⁴ C-Saytex 8010: Absorption, Distribution, Metabolism, Excretion, and Pharmacokinetics Following a Single Intravenous or Oral Administration to Rats	Midwest Research Institute	2004
Studies to Investigate the Absorption, Distribution, and Metabolism of 9161-200 A, 9161-200 B, 9161-200 C, and 9161-200 D	Cyprotex Discovery, Ltd.	2008
Fish acute toxicity	Wildlife International	2003
SAYTEX 8010 DETERMINATION OF WATER SOLUBILITY BY THE GENERATOR COLUMN METHOD	Wildlife International	1999
Determination of polybrominated dibenzofurans (PBDFs) and polybrominated dibenzo-p-dioxins (PBDDs) in different plastics containing the brominated flame retardant BrFR1 of the Ethyl Corporation, USA	Gesellschaft für Arbeitsplatz- und Umweltanalytik mbH (GfA)	1995
DETERMINATION OF THE VAPOR PRESSURE OF SAYTEX 8010 USING THE SPINNING ROTOR GAUGE METHOD	Wildlife International	2002
Test on bioaccumulation of SAYTEX-402 in carp	Kurume Research Laboratories	1991
Ames/Salmonella plate incorporation assay	Pharmakon	1988
Rabbit eye irritation	Pharmakon	1988
SALMONELLA/MAMMALIAN-MICROSOME PLATE INCORPORATION MUTAGENICITY ASSAY (AMES TEST) AND ESCHERICHIA COLI WP2 uvrA REVERSE MUTATION ASSAY	Microbiological Associates, Inc.	1991
CHROMOSOME ABERRATIONS IN CHINESE HAMSTER LUNG (CHL) CELLS	Microbiological Associates, Inc.	1991
Rabbit skin irritation	Pharmakon	1988
Rat acute oral toxicity	Institut Francais de Recherches et Essais Biologiques	1982
Rabbit acute dermal toxicity	Pharmakon	1988
S8010: Soil Microorganisms: Nitrogen Transformation Test	Wildlife International	2008

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S8010 A TOXICITY TEST TO DETERMINE THE EFFECTS OF THE TEST SUBSTANCE ON SEEDLING EMERGENCE OF SIX SPECIES OF PLANTS	Wildlife International	2005
S8010: AN ACTIVATED SLUDGE, RESPIRATION INHIBITION TEST	Wildlife International	2008
Daphnia acute toxicity	Wildlife International	2003
Test on biodegradability of SAYTEX-402 by microorganisms	Kurume Research Laboratories	1991
SAYTEX 8010 DETERMINATION OF THE n-OCTANOL/WATER PARTITION COEFFICIENT BY THE GENERATOR COLUMN METHOD	Wildlife International	1999
Rat 90-day repeated-dose oral toxicity	Pharmakon	1992
DEVELOPMENTAL TOXICITY (TERATOLOGY) STUDY IN RATS WITH SAYTEX 402	Springborn Laboratories Inc.	1992
SAYTEX 8010: ADSORPTION/DESORPTION CHARACTERISTICS IN REPRESENTATIVE SOILS, SEDIMENTS, AND ACTIVATED SLUDGE SOLIDS	Wildlife International	2015
SAYTEX 8010: BIODEGRADATION IN ANAEROBIC DIGESTER SLUDGE	Wildlife International	2011
S8010: A Prolonged Sediment Toxicity Test with <i>Chironomus riparius</i> Using Spiked Sediment	Wildlife International	2003
DBDPethane: ANAEROBIC TRANSFORMATION IN SOIL	Wildlife International	2015
A 96-hour toxicity test with the freshwater algae (<i>Selenastrum capricornutum</i> / <i>Pseudokirchneria subcapita</i>)	Wildlife International	2003
Pharmacokinetic Studies of [¹⁴ C]Decabromodiphenyl ethane (EBP), Rats	Research Triangle Institute	2012
S8010: A REPRODUCTION STUDY WITH THE NORTHERN BOBWHITE	Wildlife International	2013
Studies to Investigate the Absorption, Distribution, and Metabolism of 9161-200 A, 9161-200 B, 9161-200 C, and 9161-200 D	Cyprotex Discovery Ltd.	2008
S8010: A Prolonged Sediment Toxicity Test With <i>Lumbriculus variegatus</i> Using Spiked Sediment With 2% Total Organic Carbon	Wildlife International	2003
Effects of Saytex 8010 on the Survival and Reproduction of the Earthworm, <i>Eisenia fetida</i>	Wildlife International	2003
DBDPethane: AEROBIC TRANSFORMATION IN SOIL	Wildlife International	2015
Degradation - Aerobic and Anaerobic Sediment, OECD 308	Wildlife International	2015

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Validation report for the determination of the limit of quantitation of lower brominated components in a Saytex sample with GC/FID and GC/M	SGS Belgium	2014
Determination of Polyhalogenated Dibenzo-p-Dioxins and Dibenzofurans in the Combustion Products From the Laboratory Simulation of the Municipal Waste Incineration of Ethyl Corporation PMN Substance 89-867	Ethyl Technical Center	1993
DEVELOPMENTAL TOXICITY (TERATOLOGY) STUDY IN RABBITS WITH SAYTEX 402	Springborn Laboratories Inc.	1992
Rat oral repeated-dose (28 d) toxicity	Pharmakon	1991
Octanol solubility	Albemarle Product Development Center	2013
Analysis of nonabromodiphenylethane and decabromodiphenylethane in Saytex S-8010 and in HIPS Sb ₂ O ₂ formulated with S-8010	Albemarle Product Development Center	2007
¹⁴ C-DECABROMODIPHENYL ETHANE: A 48-HOUR BRIDGING STUDY TO ESTIMATE THE CONCENTRATIONS OF DECABROMODIPHENYL ETHANE IN TEST SOLUTIONS DURING A PREVIOUSLY CONDUCTED 48-HOUR ACUTE TOXICITY TEST WITH <i>Daphnia magna</i>	EAG Laboratories	2017
¹⁴ C-DECABROMODIPHENYL ETHANE: A 96-HOUR BRIDGING STUDY TO ESTIMATE THE CONCENTRATIONS OF DECABROMODIPHENYL ETHANE IN TEST SOLUTIONS DURING A PREVIOUSLY CONDUCTED 96-HOUR ACUTE TOXICITY TEST WITH RAINBOW TROUT (<i>Oncorhynchus mykiss</i>)	EAG Laboratories	2017
¹⁴ C-DECABROMODIPHENYL ETHANE: A 96-HOUR BRIDGING STUDY TO ESTIMATE THE CONCENTRATIONS OF DECABROMODIPHENYL ETHANE IN TEST SOLUTIONS DURING A PREVIOUSLY CONDUCTED 96-HOUR TOXICITY TEST WITH THE FRESHWATER ALGA (<i>Pseudokirchneriella subcapitata</i>)	EAG Laboratories	2017
Degradation Soil with plants	EAG Laboratories	2019
EBP: Environmental Exposure Assessment Report	Peter Fisk Associates	2019
Recycling Studies of High-Impact Polystyrene containing SAYTEX® 8010 and Antimony Trioxide	Albemarle Product Development Center	2018
EBP: the absence of polybrominated dibenzofurans and dibenzo-p-dioxins in the substance and in	Peter Fisk Associates	2019

Appendix VI

polymer formulations before and after exposure to high temperatures and incineration FINAL REPORT CONFIDENTIAL Reference: PFA.893.002.001 Authors: Stephen Summerfield		
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