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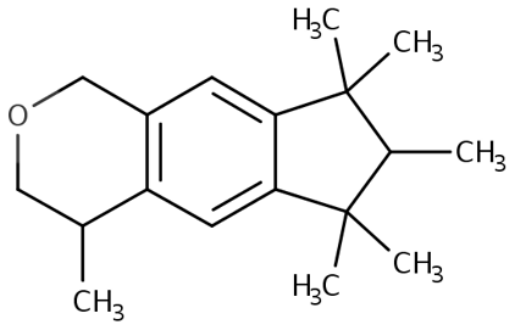
Office of Chemical Safety and
Pollution Prevention

Draft Systematic Review Protocol for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)

Systematic Review Support Document for the Draft Risk Evaluation

CASRN 1222-05-5



March 2026

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1 INTRODUCTION

The U.S. EPA's Office of Pollution Prevention and Toxics (OPPT) applies systematic review principles in the development of risk evaluations under the amended Toxic Substances Control Act (TSCA). TSCA section 26(h) requires EPA to use scientific information, technical procedures, measures, methods, protocols, methodologies, and models consistent with the best available science and base decisions under section 6 of TSCA on the weight of the scientific evidence. Within the TSCA risk evaluation context, the weight of the scientific evidence is defined as "a systematic review method, applied in a manner suited to the nature of the evidence or decision, that uses a pre-established protocol to comprehensively, objectively, transparently, and consistently identify and evaluate each stream of evidence, including strengths, limitations, and relevance of each study and to integrate evidence as necessary and appropriate based upon strengths, limitations, and relevance" (40 CFR 702.33).

To meet the TSCA section 26(h) science standards, EPA used the TSCA systematic review process described in the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (U.S. EPA, 2021) (also referred to as "2021 Draft Systematic Review Protocol"). Section 3 of the 2021 Draft Systematic Review Protocol depicts the steps in which information is identified and whether it undergoes the formal systematic review process (U.S. EPA, 2021). Information attained via the systematic review process is integrated with information attained from sources of information that do not undergo systematic review (*e.g.,* EPA-generated model outputs) to support a weight of the scientific evidence analysis (Figure 1-1).

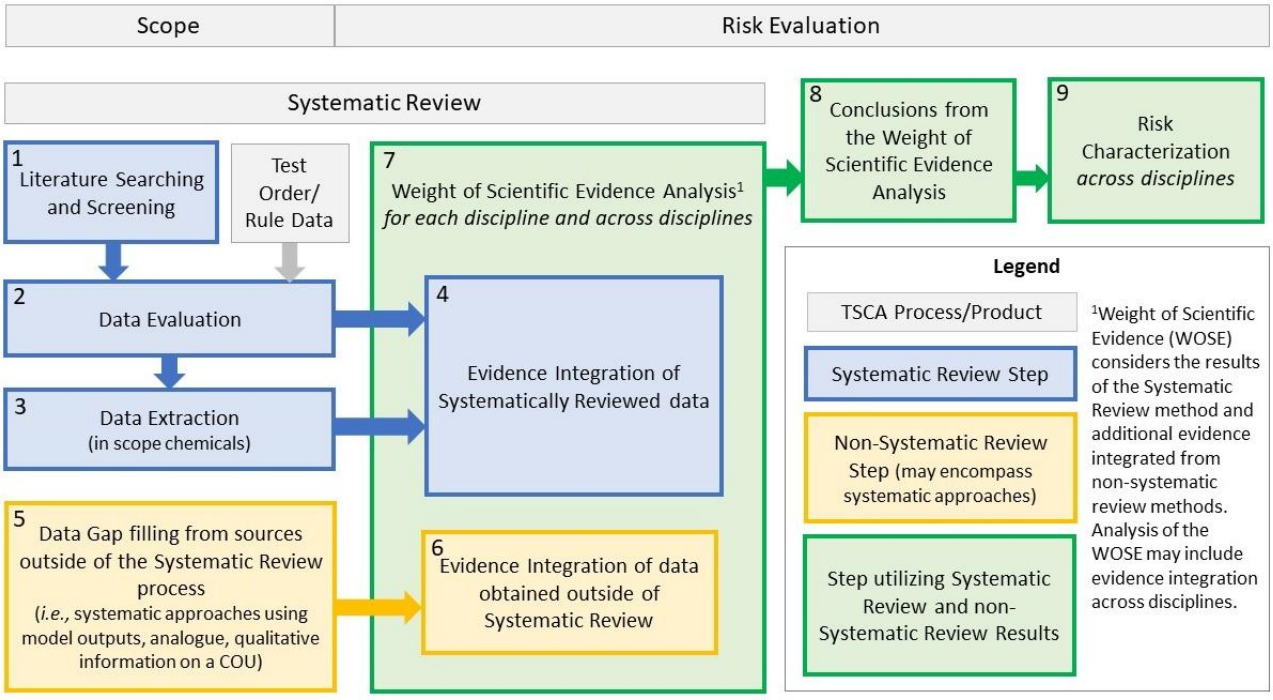

Figure 1-1. Overview of the TSCA Risk Evaluation Process with Identified Systematic Review Steps

The process complements the risk evaluation process in that it is used to develop the exposure and hazard assessments based on reasonably available information. EPA defines "reasonably available information" to mean information that EPA possesses or can reasonably obtain and synthesize for use in risk evaluations, considering the deadlines for completing the evaluation (40 CFR 702.33).

2 CLARIFICATIONS AND UPDATES TO THE 2021 DRAFT SYSTEMATIC REVIEW PROTOCOL

In 2021, EPA released the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), a framework of systematic review approaches under TSCA, to address comments received on a precursor systematic review approaches framework, the *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2018). In April 2022, the SACC provided comments on the 2021 Draft Systematic Review Protocol and additional comments on OPPT's systematic review approaches were garnered during the public comment period. In lieu of an update to the 2021 Draft Systematic Review Protocol, this systematic review protocol for the *Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026m) (also referred to as "Draft Risk Evaluation for HHCB"; see also public docket, EPA-HQ-OPPT-2018-0430) describes some clarifications and different approaches that were implemented than those described in the 2021 Draft Systematic Review Protocol in response to (1) SACC comments, (2) public comments, or (3) to reflect chemical-specific risk evaluation needs.

2.1 Clarifications

The chemical-specific systematic review protocol is used to transparently document any updates or clarifications made to the systematic review process used for considering information identified for a given TSCA risk evaluation, as compared to those published in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Throughout the 2021 Draft Systematic Review Protocol, there were some terms used that were not explicitly defined, resulting in their different uses within the document (U.S. EPA, 2021). Table 2-1 lists the terms that were updated to resolve some of the confusion expressed by the public and SACC comments regarding the implementation of the respective systematic review-related step. One main clarification is that *all references that undergo systematic review are considered for use in the risk evaluation*, even those that do not meet the various discipline and sub-discipline screening criteria or those that are categorized as supplemental information at title and abstract (TIAB) or full-text (FT) screening.

Section 4.2.5 of the 2021 Draft Systematic Review Protocol describes how data sources (*e.g.,* individual references, databases) may be tagged and linked in when the same information is present in multiple publications (U.S. EPA, 2021). References will generally undergo data quality evaluation and extraction if there are data that pass screening criteria; however, to prevent the same data from being represented multiple times and conflating the amount of available information there is on a subject area, if two or more references contain the same results tables, EPA selects the reference(s) that most thoroughly describes the extractable results (indicated as the parent reference in DistillerSR). If two references portray the same information from the same dataset, only one is counted in the overall dataset (*i.e.,* deduplication). If two references contain information about the same dataset, but one of those references only provides additional contextual information or summary statistics (*e.g.,* mean), both data sources are linked but the extractable information from both may be combined in DistillerSR. This enables the capture of key information while avoiding double-counting the data of interest. The linked reference containing most of the data, which are evaluated and extracted, is identified in DistillerSR as the parent reference; the "complementary child reference" in DistillerSR does not undergo independent data evaluation and extraction but is evaluated and extracted in combination with the parent reference. Linking the references in DistillerSR allows the reference with more limited information or only contextual information to be tracked and utilized to evaluate the extracted data in the other related studies. The child reference may undergo data quality evaluation and extraction if there are additional unique and original data that pass screening criteria.

Section 4.5 of the 2021 Draft Systematic Review Protocol describes how data may be obtained using TSCA authorities and test orders. One update to that section is that in addition to requiring data reporting under TSCA sections 4 (test order), 8(a) (Chemical Data Reporting [CDR]) and 8(d) (Health and Safety Data Reporting), *EPA may also require data reporting under TSCA section 8(c)* (Call-in of Adverse Reactions Records). Appendix 5.3 also describes how information may be submitted to EPA under other TSCA authorities (*e.g.,* TSCA sections 4, 5, 6, 8(d) and 8 (e), as well as FYI submissions).

Section 5 of the 2021 Draft Systematic Review Protocol describes how EPA conducts data quality evaluation of data/information sources considered for a respective chemical risk evaluation, with Section 5.2 specifically explaining the terminology used to describe both metric and overall data/information source quality determinations (U.S. EPA, 2021). To respond to both SACC and public comments regarding the inappropriate use of quantitative methodologies to calculate both "metric rankings" and "overall study rankings," *EPA decided to not implement quantitative methodologies to attain either metric and overall data/information source quality determinations* and therefore updated the terminology used for both metric ("metric ranking") and overall data/information source ("overall study ranking") quality determinations (Table 2-1). Subsequently terminology for both individual metric and overall information source quality determinations has been updated to "metric rating" and "overall quality determination," respectively. The word "level" was also often used synonymously and inconsistently with the word "ranking" in the 2021 Draft Systematic Review Protocol; that inconsistency has been rectified, resulting in the word "level" no longer being used to indicate either metric or overall data/information source quality determinations (U.S. EPA, 2021).

Sections 4.3.2.1.3 and 6 of the 2021 Draft Systematic Review Protocol describe when EPA may reach out to authors of data/information sources to obtain raw data or missing elements that are important to support the data evaluation and data integration steps (U.S. EPA, 2021). In such cases, the request(s) for additional data/information, number of contact attempts, and responses from the authors are documented. EPA's outreach is considered unsuccessful if those contacted do not respond to email or phone requests within 1 month of initial attempt(s) of contact. One important clarification to this guidance is that *EPA may reach out to authors anytime during the systematic review process for a given data/information source or reference, and that contacting authors does not explicitly happen during the data quality evaluation or extraction step.*

Table 2-1. Terminology Clarifications Between the 2021 Draft Systematic Review Protocol and the Draft Risk Evaluation for HHCB

2021 Draft Systematic Review Protocol Term	HHCB Systematic Review Protocol Term Update	Clarification
"Title and abstract" or "title/abstract"	"Title and abstract"	To increase consistency, the term "title and abstract" will be used to refer to information specific to "title and abstract" screening.
Variations of how "include," "on topic" or "PECO[a]/PESO[b]/RESO[c] relevant" implied a reference was considered for use in the risk evaluation, whereas "exclude," "off topic" or "not	Meets/does not meet PECO[a]/ PESO[b]/RESO[c] screening criteria	The term "include" or "exclude" falsely suggests that a reference was or was not, respectively, considered in the risk evaluation. There was also confusion regarding whether "on topic" and "PECO[a]/PESO[b]/RESO[c] relevant" were synonymous and suggested those references were explicitly considered for use in the risk evaluation (and by default, "off topic" and "not PECO[a]/PESO[b]/RESO[c] relevant" references were not). References that meet the

2021 Draft Systematic Review Protocol Term	HHCB Systematic Review Protocol Term Update	Clarification
PECO[a]/PESO[b]/RESO[c] relevant" implied a reference was *not* considered for use in the risk evaluation.		screening criteria proceed to the next systematic review step; however, all references that undergo systematic review at any time are considered in the risk evaluation. Information that is categorized as supplemental or does not meet screening criteria are generally less relevant for quantitative use in the risk evaluation but may be considered if there is a data need identified. For instance, mechanistic studies are generally categorized as supplemental information at either title and abstract or full-text screening steps but may undergo the remaining systematic review steps if there is a relevant data need for the risk evaluation (*e.g.,* dose response, mode of action).
Database source not unique to a chemical	Database	Updated term and definition of "Database": Data obtained from databases that collate information for the chemical of interest using methods that are reasonable and consistent with sound scientific theory and/or accepted approaches and are from sources generally using sound methods and/or approaches (*e.g.,* state or federal governments, academia). Example databases include STORET (STOrage and RETrieval) and the Massachusetts Energy and Environmental Affairs Data Portal. The term in the 2021 Draft Systematic Review Protocol (Table_Apx N-1) incorrectly suggested that databases that contain information on a singular chemical are not considered (U.S. EPA, 2021). Furthermore, the wording "large" was removed to prevent confusion and the incorrect suggestion that there is a data size requirement for databases that contain information that may be considered for systematic review.
Metric Ranking or Level	Metric Rating	As explained above, EPA is not implementing quantitative methodologies to indicate metric quality determinations, therefore the term "ranking" is inappropriate. The term "level" was inconsistently used to indicate metric quality determinations previously; therefore, EPA is removing the use of this term to reduce confusion when referring to metric quality determinations. The term "Rating" is more appropriate to indicate the use of professional judgement to determine a quality level for individual metrics.
Overall Study Ranking or Level	Overall Quality Determination (OQD)	As explained above, EPA is not implementing quantitative methodologies to indicate overall data/information source quality determinations, therefore the term "ranking" is inappropriate. The term "level" was inconsistently used to indicate overall data/information source quality determinations previously; therefore, EPA

2021 Draft Systematic Review Protocol Term	HHCB Systematic Review Protocol Term Update	Clarification
		is removing the use of this term to reduce confusion when referring to overall data/information source quality determinations. The term "Rating" is more appropriate to indicate the use of professional judgement to determine a quality level for the overall data/information source quality determination.
Sub-discipline	No change in term	Sub-discipline explicitly indicates the two categories of receptor-based studies relevant to evaluate human health hazard (discipline): epidemiological (human receptor) or human health animal model toxicological studies (non-human animal receptor). Although environmental hazard is a discipline, Appendix T incorrectly suggested that environmental hazard is a sub-discipline in the 2021 Draft Systematic Review Protocol.
Evidence Stream	No change in term	Evidence streams were updated for both environmental and human health hazard disciplines to more appropriately categorize the hazardous endpoints that were considered. Please see additional descriptions of the evidence stream updates in Section 6.5 below.

[a] "PECO" stands for population, exposure, comparator or scenario, and outcomes.
[b] "PESO" stands for pathways or processes, exposure, setting or scenario, and outcomes.
[c] "RESO" stands for receptors, exposure, setting or scenario, and outcomes.

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3 DATA SEARCH

As described in Section 4 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), EPA conducts a comprehensive search for reasonably available information to support the TSCA risk evaluations. Chemical-specific literature searches are conducted as described in Section 4.2.1 of the 2021 Draft Systematic Review Protocol for all disciplines (*i.e.,* physical and chemical properties, environmental fate and transport properties, engineering, exposure, environmental hazard, and human health hazard) (U.S. EPA, 2021). Additional details on the chemical verification process, and the methodology used to search for chemical specific peer-reviewed and gray literature is available in Sections 4.2 and 4.3 of the 2021 Draft Systematic Review Protocol, respectively (U.S. EPA, 2021). The search for peer-reviewed and gray literature relevant references was completed in September and May 2019, respectively. Appendix Section C.1.10 of the 2021 Draft Systematic Review Protocol contains the specific search strings used to identify peer-reviewed literature on HHCB (U.S. EPA, 2021). All reasonably available information submitted to EPA under TSCA authorities was considered.

An updated literature search for potential additional sources of information and data that might support the HHCB risk evaluation was conducted in May 2025. Details for the updated literature search and consideration of the new information are described in Section 3.1 of this chemical-specific systematic review protocol.

3.1 Multi-Disciplinary Updates and Clarifications to the Data Search

For the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m), the literature search (both initial and updated search) was conducted as described in Section 4 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). The peer-reviewed and gray literature search followed the approach outlined in Sections 4.2 and 4.3 of the 2021 Draft Systematic Review Protocol, respectively (U.S. EPA, 2021). Occasionally additional data sources relevant for the risk evaluation may be identified after the initial search for peer-reviewed and gray literature; these data sources will then undergo systematic review for the relevant discipline(s). Additionally, each discipline uses different strategies (*e.g.,* search strings) to attain their discipline-specific pools of data sources that undergo systematic review.

Updated Literature Search

An update to the peer-reviewed literature search to capture information published since September 2019 was performed in May 2025 to identify any potential additional data sources for environmental and human health hazard that might have been identified since the initial literature search was conducted in 2019 for HHCB. Other disciplines considered to have sufficient information to support the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m) and did not proceed with an update to the peer-reviewed literature. Table 3-1 lists the details for the literature search strategies for HHCB. To clarify, the literature search strategy as described in Section 4 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) was the same for the initial search in 2019 as it was for the search in February 2025. For full transparency, the literature results in Table 3-1 indicate the number of references obtained during the initial search, the updated search, as well as the total number of references identified for HHCB. The literature search strategies described in Table 3-1 are chemical-specific but discipline-agnostic. To identify discipline-specific pools of data sources for environmental and human health hazard that undergo systematic review, EPA applied the same discipline-specific strategies (*e.g.,* search strings) in the updated literature search performed in May 2025 as it did in the initial literature search in 2019. Details on the number of references identified for environmental and human health hazard as a result of the updated literature search are described in 3.6.

Table 3-1. Peer Literature Search Strategies for HHCB

Source	Search Strategy
ProQuest	TIAB("Galaxolide" OR "HHCB" OR "1222-05-5" OR "Abbalide" OR "Galoxolide" OR "Pearlide" OR "Cyclopenta[g]-" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran" OR "Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-gamma-2-benzopyran" OR "4,6,6,7,8,8-Hexamethyl" OR "1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [g]-2-benzopyran, HHCB" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta-gamma-2-benzopyran" OR "(4S,7R)-1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran")
PubMed	("Galaxolide"[tw] OR "HHCB"[tw] OR "1222-05-5"[rn] OR "Abbalide"[tw] OR "Galoxolide"[tw] OR "Pearlide"[tw] OR "Cyclopenta[g]-"[tw] OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran"[tw] OR "Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-gamma-2-benzopyran"[tw] OR "4,6,6,7,8,8-Hexamethyl"[tw] OR "1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl"[tw] OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [g]-2-benzopyran, HHCB"[tw] OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta-gamma-2-benzopyran"[tw] OR "(4S,7R)-1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran"[tw])
Scopus	TITLE-ABS({Galaxolide} OR {HHCB} OR {1222-05-5} OR {Abbalide} OR {Galoxolide} OR {Pearlide} OR {Cyclopenta[g]-} OR {1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran} OR {Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-gamma-2-benzopyran} OR {4,6,6,7,8,8-Hexamethyl} OR {1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl} OR {1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [g]-2-benzopyran, HHCB} OR {1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta-gamma-2-benzopyran} OR {(4S,7R)-1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran})
WoS	TS=("Galaxolide" OR "HHCB" OR "1222-05-5" OR "Abbalide" OR "Galoxolide" OR "Pearlide" OR "Cyclopenta[g]-" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran" OR "Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-gamma-2-benzopyran" OR "4,6,6,7,8,8-Hexamethyl" OR "1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [g]-2-benzopyran, HHCB" OR "1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta-gamma-2-benzopyran" OR "(4S,7R)-1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran")
Literature Results	Initial Search – 656, Update Search: 286, Total Literature: 942

SWIFT-Review Validation

EPA received comments regarding the lack of detail on the use and validation of SWIFT-Review to determine discipline-specific peer-reviewed reference set considered for use in TSCA risk evaluations. In response to those comments, EPA conducted validation exercises to clarify the search process and build consistency among all the disciplines. The 2021 Draft Systematic Review Protocol contains validation results for the use of SWIFT-Review to determine which peer-reviewed references may be relevant for the characterization of occupational exposure and environmental releases and general population, consumer, and environmental exposure for the respective chemical risk evaluations. However, to expand upon the information provided in the 2021 Draft Systematic Review Protocol, EPA validated references relevant for determining chemical-specific peer-reviewed reference set for the characterization of physical and chemical properties, environmental fate and transport properties, and environmental and human health hazard. EPA manually screened the references that were found in the overall peer-reviewed search results that did not undergo TIAB screening (*i.e.,* references that were not identified using a discipline-specific search string). If a reference that did not undergo further review after TIAB screening was found to meet the screening criteria for a respective discipline (*e.g.,* data needs on physical chemical properties, environmental fate and transport properties, and environmental and human health hazard) and identified for the chemical of interest, it was flagged as a false negative.

This analysis validated and verified the use of the search terms in SWIFT-Review, as it showed that less than 5 percent of references were false negatives across all three disciplines. This method was repeated for several of the TSCA High Priority Substances to build confidence in our discipline-specific search strings.

Supplemental Filtering of 2019 Literature Search for Dermal Absorption

Dermal absorption studies are needed to accurately assess dermal exposure associated with specific conditions of use. Typically, dermal absorption studies are identified as supplemental studies within the human health hazard discipline using the hazard PECOs presented in Appendix H of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). However, dermal absorption data may not meet the screening criteria for other disciplines; these criteria are also presented in Appendix H of U.S. EPA (2021).

To identify any additional studies not found during hazard screening that might be potentially relevant for characterizing dermal absorption and exposure, EPA developed a key word list (identified as a search string in Section 3.7.1 below) and used SWIFT-Review to search/filter the data sources that were previously identified in the HHCB chemical search conducted in 2019. EPA followed processes described in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Within the 2021 Draft Systematic Review Protocol, Section 4.2.2 outlines when EPA uses supplemental searching and filtering; and Section 4.2.4 presents the process of using SWIFT-Review to filter data sources identified in the initial chemical search (U.S. EPA, 2021).

Additional Gray Literature Sources

Physical and Chemical Properties: In addition to the gray literature sources listed in Appendix E of the 2021 Draft Systematic Review Protocol, an additional database was added to the list of gray literature sources for physical and chemical properties. The National Institutes for Standards and Technology (NIST) Chemistry Webbook was searched in September 2021 to capture spectroscopic data, specifically ultra-violet and visible absorption (UV-Vis) data, if recorded. This source may also provide thermodynamic data that informs chemical stability and behavior under various conditions.

General Population, Consumer, and Environmental Exposure: In addition to the gray literature sources listed in Appendix E of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), an additional source was added in 2023 to capture database outputs from a governmental source. Because the literature pool for many chemicals, including HHCB, includes a record from EPA's STORET database, which has been retired, EPA downloaded all the data for this chemical from the Water Quality Portal (WQP), which results from a collaboration between EPA, the U.S. Geological Survey, and the National Water Quality Monitoring Council, the successor database that now contains data from STORET. This data was uploaded into HERO and added to the literature pool that is considered for systematic review.

3.2 Physical and Chemical Properties

The search for peer-reviewed and gray literature are as described in Sections 4.2 and 4.3, respectively, in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). SWIFT-Review was used to identify peer-reviewed references that are predicted to be the most relevant for evaluating physical and chemical properties for HHCB. Specifically, the search string used to identify data sources that potentially contain physical and chemical property information on HHCB in SWIFT-Review was developed by EPA's Office of Research and Development (ORD) in collaboration with Sciome and is presented in Appendix G, Section G-1, Table_Apx G-1 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). As mentioned above in Section 3.1, the search string used to identify potentially relevant peer-reviewed data references for evaluation of the physical and chemical properties of HHCB was validated. When the

search string terms are identified in the title, abstract or as a keyword of a given reference in SWIFT-Review, those references proceed with title and abstract screening. EPA considered to have sufficient information gathered since the literature search conducted in 2019 in addition to information obtained via public or other sources (*e.g.,* chemical assessor identified, backward searches) on the physical and chemical properties to support the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m) and did not proceed with an update to the peer-reviewed literature in 2025.

3.3 Environmental Fate and Transport Properties

The search for peer-reviewed and gray literature are as described in Sections 4.2 and 4.3, respectively, in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Specifically, SWIFT-Review was used to identify peer-reviewed references that are predicted to be the most relevant for evaluating environmental fate and transport properties for HHCB. The search string used for environmental fate and transport literature in SWIFT-Review was developed by EPA's ORD in collaboration with Sciome and is presented in Appendix G, Section G.2, Table_Apx G2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). As mentioned above in Section 3.1, the search string used to identify potentially relevant peer-reviewed data references for evaluation of the environmental fate and transport properties of HHCB were validated. When the search string terms are identified in the title, abstract or as a keyword of a given reference in SWIFT-Review, those references proceed with TIAB screening. EPA considered to have sufficient information gathered since the literature search conducted in 2019 in addition to information obtained via public or other sources (*e.g.,* chemical assessor identified, backward searches)on environmental fate and transport properties to support the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m) and did not proceed with an update to the peer-reviewed literature in 2025.

3.4 Environmental Release and Occupational Exposure

The searches for peer-reviewed and gray literature are described in Sections 4.2 and 4.3, respectively, in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Specifically, SWIFT-Review was used to identify peer-reviewed references that are predicted to be the most relevant for evaluating environmental release and occupational exposure for the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m). As described in Sections 4.2.4.2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), EPA identified on-topic and off-topic references from the broad search results of the HHCB peer-reviewed literature as positive and negative "seeds" to classify which references contained environmental release and occupational exposure to prioritize for further review. When the relevant references were identified in SWIFT Review, those references proceeded with title and abstract screening. EPA considered to have sufficient information gathered since the literature search conducted in 2019 in addition to information obtained via public or other sources (*e.g.,* chemical assessor identified, backward searches) on environmental release and occupational exposure information to support the Draft Risk Evaluation for HHCB (U.S. EPA, 2026m) and did not proceed with an update to the peer-reviewed literature in 2025.

3.5 General Population, Consumer, and Environmental Exposure

The peer-reviewed and gray literature searches for general population, consumer, and environmental exposure are as described in Sections 4.2 and 4.3, respectively, in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Specifically, SWIFT-Review was used to identify peer-reviewed references that are predicted to be the most relevant for evaluating general population, consumer, and environmental exposures to HHCB. As described in Sections 4.2.4.2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), EPA identified on-topic and off-topic references from the broad search results of the peer-reviewed literature as positive and negative "seeds" to classify which references on general population, consumer, and environmental exposures to prioritize for further review.

As noted previously in Section 3.1, one additional reference was added to the literature search protocol to capture database data from the WQP. The database data were compared to other database and monitoring data found during the literature search to ensure no duplication of data. A record from a predecessor database to WQP, EPA's STORET database, that was found during the literature search was not counted as a separate reference to avoid double-counting data. There were no other changes to the process identified in the 2021 Draft Systematic Review Protocol for information considered for the evaluation of general population, consumer, and environmental exposure to HHCB (U.S. EPA, 2021). EPA considered to have sufficient information gathered since the literature search conducted in 2019 in addition to information obtained via public or other sources (*e.g.,* chemical assessor identified, backward searches) on general population, consumer, and environmental exposure information to support the *Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026m) and did not proceed with an update to the peer-reviewed literature in 2025.

3.6 Environmental and Human Health Hazard

The searches for peer-reviewed and gray literature were conducted as described in Sections 4.2 and 4.3, respectively, in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Specifically, SWIFT-Review was used to identify peer-reviewed references that are predicted to be relevant for evaluating environmental and human health hazards for HHCB. Specifically, search strings were developed for the two hazard disciplines by EPA's Office of Research and Development (ORD) in collaboration with SWIFT-Review developer, Sciome. As mentioned above in Section 3.1, the search strings used to identify potentially relevant peer-reviewed references for evaluation of the environmental and human health hazard of HHCB were validated. If the search string terms were identified in the title, abstract, or as a keyword of a given reference in SWIFT-Review, then those references proceeded to TIAB screening. The environmental and human health hazard search strings are provided online.

As described in Section 3.1, an update to the peer-reviewed literature search to capture information published since September 2019 was performed in May 2025 to identify any potential additional data sources for environmental and human health hazard that might have been identified since the initial literature search was conducted in 2019 for HHCB. The literature search strategy was the same for the initial search in 2019 as it was for the search in May 2025. From the update to the peer-reviewed literature search, EPA identified 172 new additional sources of data that were screened as described in Section 4.6.

3.7 Dermal Absorption

As described above in Section 3.1, EPA used a key word list (search string) to filter the literature identified in the 2019 HHCB search to find potentially relevant information for the characterization of dermal absorption of HHCB. The search string is listed below (Section 3.7.1).

3.7.1 Dermal Absorption Search String

"Dermal flux" OR "Skin flux" OR "Dermal penetration" OR "Skin penetration" OR "Dermal absorption fraction" OR "Absorption fraction" OR "Neat Kp" OR "Aqueous Kp" OR "Kp" OR "Skin permeability coefficient" OR "Permeability coefficient" OR "Skin permeation coefficient" OR "Permeation coefficient" OR "Skin permeation" OR "Skin absorption" OR "Dermal absorption" OR "Dermal permeation" OR "OECD 427" OR "OECD 428"

4 DATA SCREENING

Sections 4.2.5 and 4.3.2 of the 2021 Draft Systematic Review Protocol describe how TIAB and full-text screening respectively, are conducted to identify references that may contain relevant information for use in risk evaluations under TSCA using discipline-specific screening criteria (U.S. EPA, 2021). Specifically, TIAB screening efforts may be conducted using the specialized web-based software programs DistillerSR[1] and SWIFT-Active-Screener,[2,3] and the below sub-sections will describe whether TIAB screening was done manually in DistillerSR or utilized machine learning to help prioritize reference screening in SWIFT-Active-Screener. Additional details on how SWIFT Active-Screener utilizes a machine-learning algorithm to automatically compute which unscreened documents are most likely to be relevant[4] are available in Section 4.2.5 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). During TIAB screening, if it was unclear whether a reference met the screening criteria (*e.g.,* PECO/RESO/PESO statements) without having the full reference to review, or if a reference was determined to meet the screening criteria, that reference advanced to full-text screening if the full reference could be retrieved and generated into a Portable Document Format (PDF).

Literature inventory trees were introduced in the scoping process for the risk evaluations that began systematic review in 2019 in response to comments received from the SACC and public to better illustrate how references underwent various systematic review steps (*e.g.,* TIAB and full-text screening). As explained in Section 2.1.2 of the *Final Scope of the Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB); CASRN 556-67-2* (U.S. EPA, 2022b), literature inventory trees demonstrate how references that meet screening criteria progress to the next systematic review step. EPA used the Health Assessment Workplace Collaborative[5] (HAWC) tool to develop web-based literature inventory trees that enhance the transparency of the decisions resulting from the screening processes; details on the application of the tool were described by Shapiro et al (2018).

Additional references identified outside of the literature searches in September 2019 or May 2025 on HHCB, but that EPA has obtained via public or other sources (*e.g.,* chemical assessor identified, backward searches) were also considered in the systematic review process and are reflected in the interactive HAWC hyperlinks available in the figure captions below each respective literature inventory tree. The web-based interactive literature inventory trees in HAWC also allow users to directly access the references in the Health and Environmental Research Online (HERO) database (more details available in Section 1 of the 2021 Draft Systematic Review Protocol) (U.S. EPA, 2021). Instructions for accessing information about references and data sources in each node via HERO are available in HAWC for each respective literature inventory tree. Each node indicates whether a reference has met screening

[1] As noted on the DistillerSR web page (accessed March 10, 2026), this systematic review software "automates the management of literature collection, triage, and assessment using AI and intelligent workflows...to produce transparent, audit ready, and compliant literature reviews." EPA uses DistillerSR to manage the workflow related to screening and evaluating references; the literature search is conducted external to DistillerSR.

[2] SWIFT-Active Screener is another systematic review software that EPA is adopting in the TSCA systematic review process. From Sciome's SWIFT-Active Screener (accessed March 10, 2026) web page: "As screening proceeds, reviewers include or exclude articles while an underlying statistical model in SWIFT-Active Screener automatically computes which of the remaining unscreened documents are most likely to be relevant. This 'Active Learning' model is continuously updated during screening, improving its performance with each reference reviewed. Meanwhile, a separate statistical model estimates the number of relevant articles remaining in the unscreened document list."

[3] SWIFT is an acronym for "*Sciome Workbench for Interactive Computer-Facilitated Text-mining.*" SWIFT-Active Screener uses machine learning approaches to save screeners' time and effort.

[4] Description comes from the SWIFT-Active Screener (accessed March 10, 2026) web page.

[5] EPA HAWC (accessed March 10, 2026) is an application that allows to record and share the results of the systematic literature search, data extraction, and analyses that can then be publicly accessed online.

criteria at different screening steps and/or contains types of content that may be discerned at that respective systematic review step (U.S. EPA, 2021). Furthermore, the sum of the numbers for the various nodes in the literature inventory trees may be smaller or larger than the preceding node because some studies may have unclear relevance or be relevant for many categories of information. The screening process for each discipline varies and the nodes in the literature inventory tree indicate the screening decisions determined for each reference and whether specific content could be determined; if no references had a specific screening decision and/or contained specific content relevant for a respective discipline, a node will not be present on the literature tree to depict this.

Occasionally some references or data sources are identified in the literature search because of the availability of the title and abstract, however EPA may not be able to always locate the entire or original version. Therefore, references or data sources that meet TIAB screening criteria may be unattainable for full-text screening. The "PDF not available" node within the literature inventory tree refers to references that were identified in the literature search, but which EPA was unable to obtain the entire reference or source of information.

While all information contained in references that enter systematic review is considered for use in the risk evaluation, the references that satisfy the screening criteria are generally deemed to contain the most relevant and useful information for characterizing the uses of, exposure to, and hazard associated with a chemical of interest and are generally utilized in the risk evaluation or to identify further data needs. On the other hand, data or information sources that do not satisfy the screening criteria outlined below may undergo data quality evaluation and extraction should a data need arise for the risk evaluation.

4.1 Multidisciplinary Updates and Clarifications to the Data Screening

As stated above in Section 1, all references that are found in the initial chemical-specific searches are considered for use in the respective chemical risk evaluation. Previously Section 4.2.5 of the 2021 Draft Systematic Review Protocol explained that references tagged as potentially having supplemental information may be considered for data quality evaluation and extraction. However, one clarification to that description is that even references that are tagged as not meeting TIAB or full-text screening criteria (*e.g.,* PECO/PESO/RESO) for a respective discipline or sub-discipline may also undergo additional screening to meet information needs that were not stated in the original screening criteria and be considered for data quality evaluation and extraction, should there be additional relevant information that may not have met the original screening criteria.

Sections 3.1 and 3.6 described that an updated peer literature search was conducted in May 2025 to identify any potential additional data sources for environmental and human health hazard that might not have been identified since the initial literature search that was conducted in 2019. The 172 additional references from the updated literature search identified to potentially have information on environmental and human health hazard were screened as previously described in Section 4.2.5 and Appendix H.5.5 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021).

4.2 Physical and Chemical Properties

During data screening, EPA followed the process described in Appendix H, Section H-1 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), to conduct title and abstract and full-text screening for HHCB guided by the data or information needs on various physical and chemical properties or endpoints as listed in Table_Apx H-1 of the protocol. The same screening criteria was used during TIAB and full-text screening for references considered for the evaluation of physical and chemical properties of HHCB. Title and abstract screening were performed using SWIFT Active-Screener. Upon meeting screening criteria during full-text screening, data or information sources then undergo data quality

evaluation and extraction. Figure 4-1 presents the number of references that report general physical and chemical property information that fulfilled the data needs for HHCB and passed these criteria for TIAB and full-text screening.

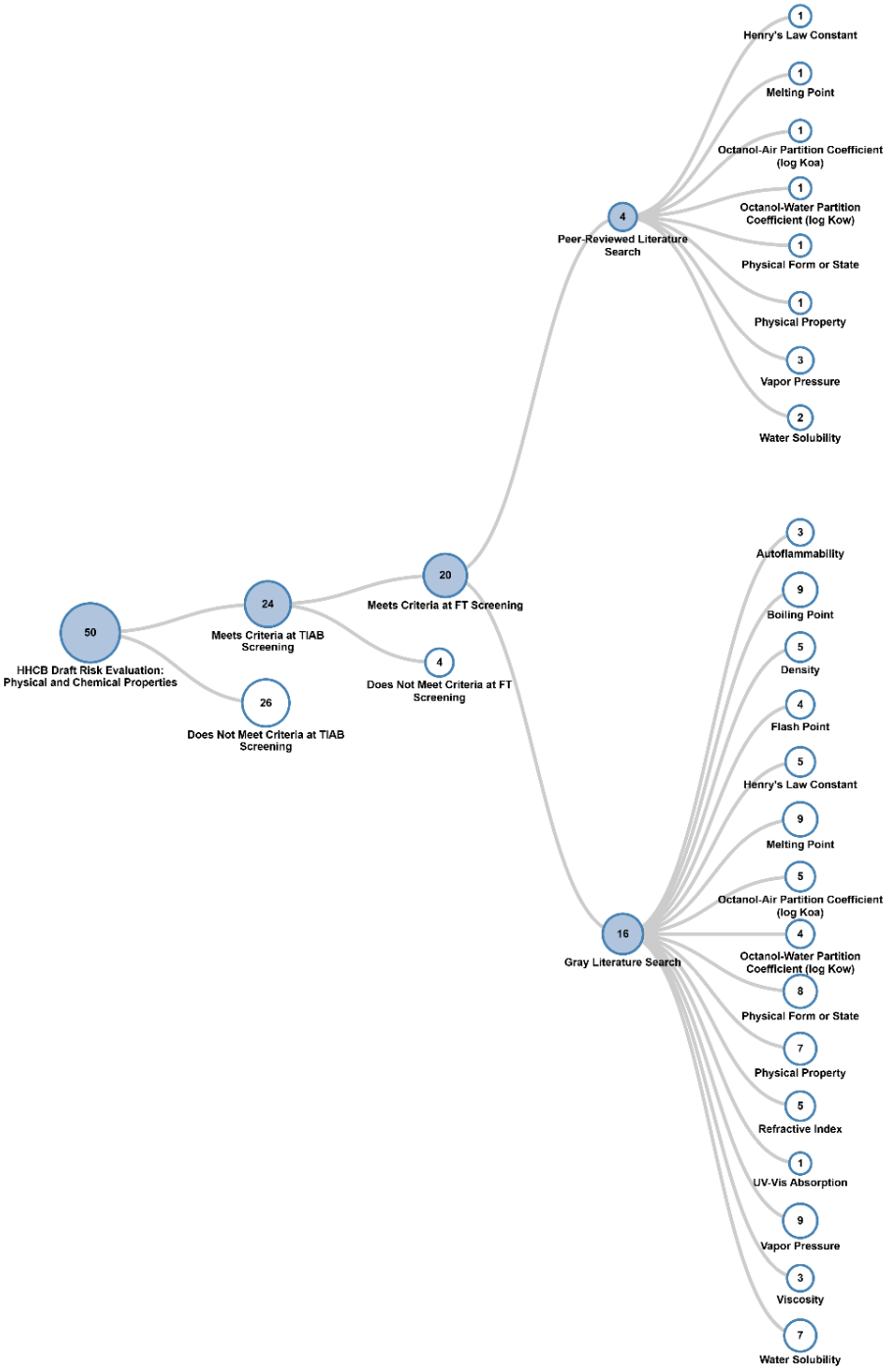

Figure 4-1. Literature Inventory Tree – Physical and Chemical Properties for HHCB
View the interactive literature inventory tree in HAWC. Data in this figure represent all references obtained from the publicly available databases and gray literature reference searches that were included in systematic review as of January 30, 2025. Additional data may be added to the interactive version as they become available. Some studies may be found through multiple searches and may have more than one source tag in HERO. Some studies may be found through multiple searches and may have more than one source tag in HERO.

4.3 Environmental Fate and Transport Properties

During data screening, EPA followed the process described in Appendix H, Section H.2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), to conduct TIAB and full-text screening for HHCB literature search results, as guided by the PESO statement. PESO stands for **P**athways or **P**rocesses, **E**xposure, **S**etting or **S**cenario, and **O**utcomes (see Table_Apx H2 in 2021 Draft Systematic Review Protocol). The same PESO screening criteria was used during TIAB and full-text screening for references considered for the evaluation of environmental fate and transport properties of HHCB. TIAB screening was performed using SWIFT Active-Screener. Data or information sources that comply with the screening criteria specified in the PESO statement then undergo data quality evaluation and extraction. Figure 4-2 presents the number of references that report HHCB fate processes and endpoints, or environmental and exposure pathways that passed PESO screening criteria at TIAB and full-text screening.

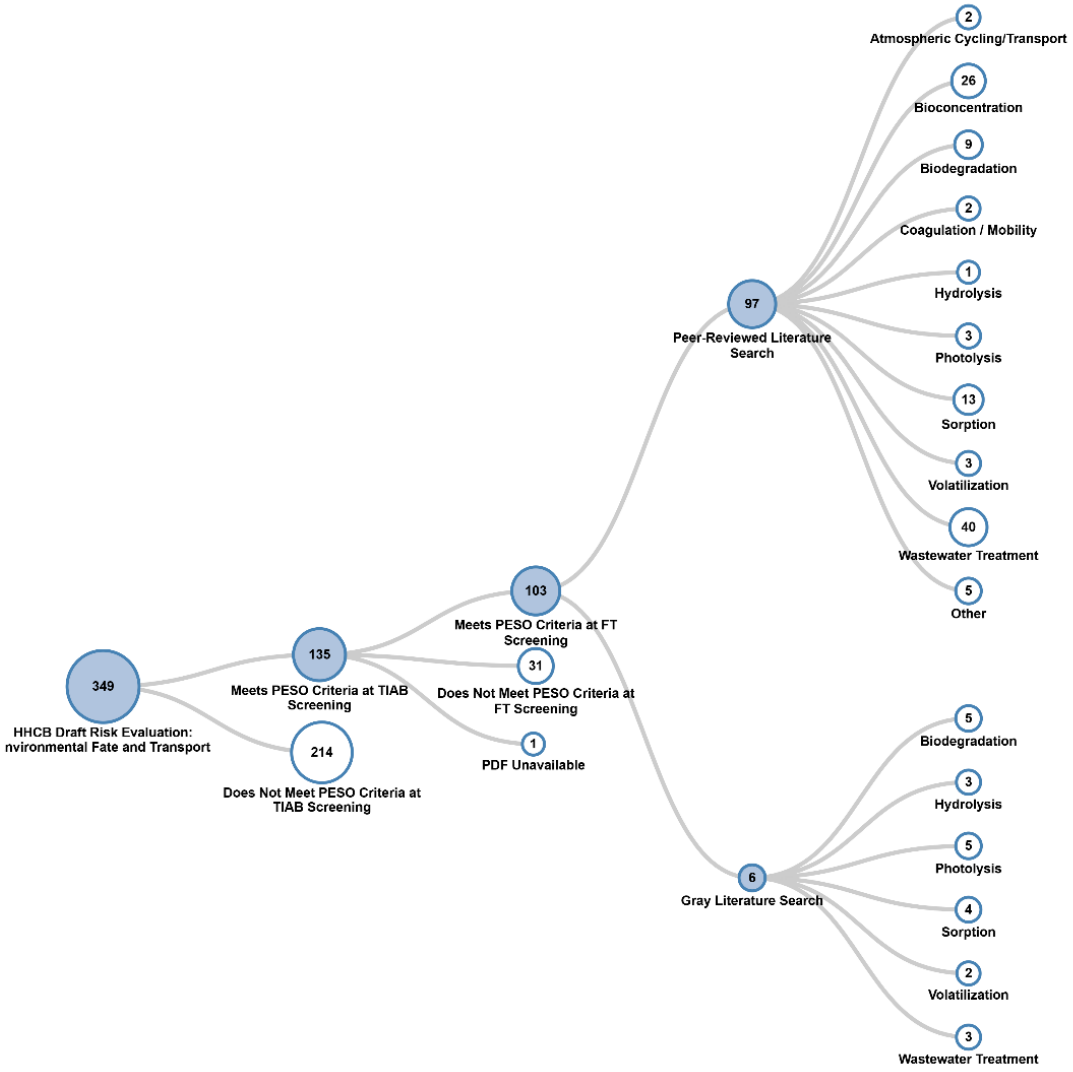

Figure 4-2. Literature Inventory Tree – Environmental Fate and Transport Properties for HHCB
View the interactive literature inventory tree in HAWC (accessed March 10, 2026). Data in this figure represent all references obtained from the publicly available databases and gray literature references searches that were included in systematic review as of August 22, 2025. Additional data may be added to the interactive version as they become available.

4.4 Environmental Release and Occupational Exposure

During data screening, EPA followed the process described in Appendix H, Section H.3 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), to conduct title and abstract, and full-text screening for HHCB literature search results, as guided by the RESO statement. RESO stands for **R**eceptors, **E**xposure, **S**etting or Scenario, and **O**utcomes. The same RESO statement was used during title and abstract, and full-text screening for references considered for the evaluation of environmental release and occupational exposure information for HHCB. TIAB were performed using SWIFT Active-Screener. Data or information sources that comply with the screening criteria specified in the RESO statement then undergo data quality evaluation and extraction. Figure 4-3 presents the number of references that report general engineering data, environmental release, and occupational exposure data that passed RESO screening criteria at TIAB, and full-text screening.

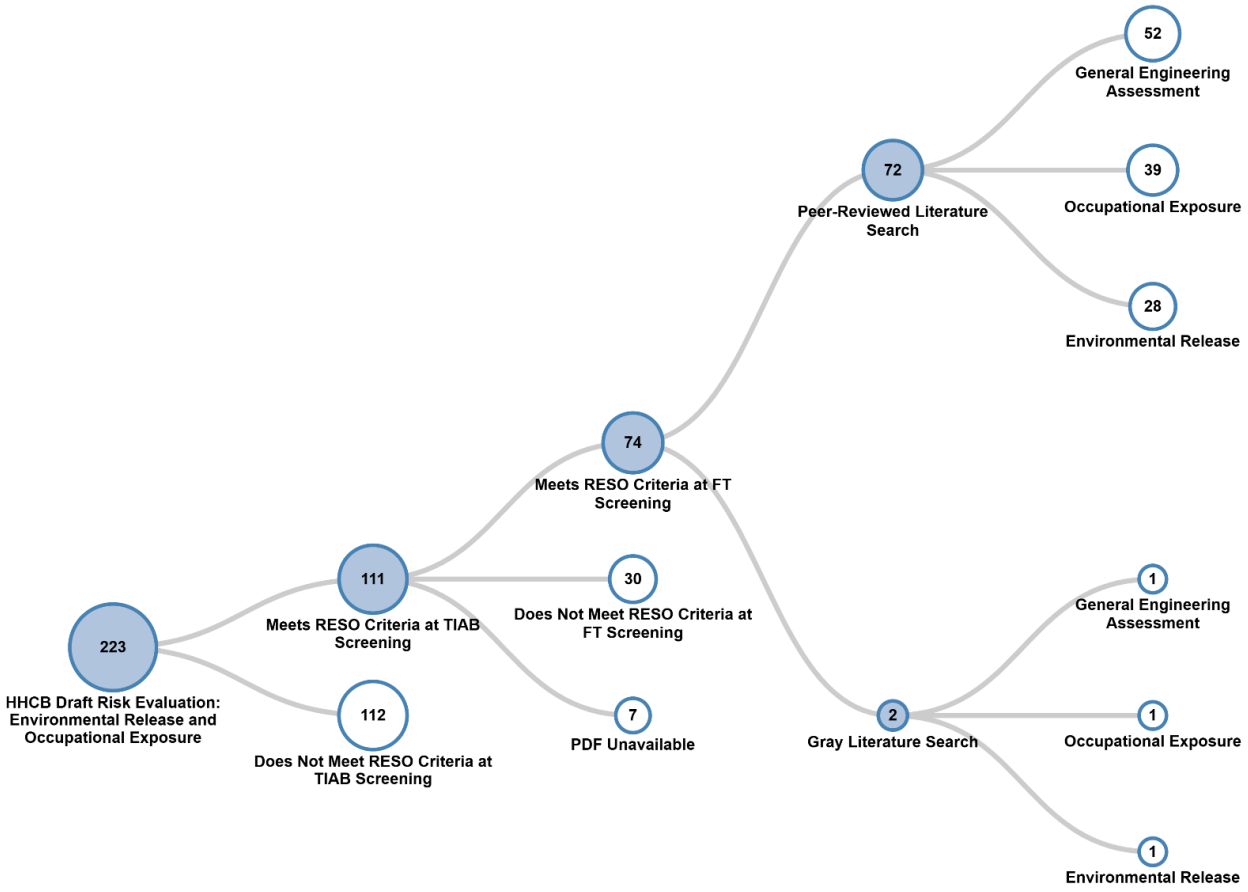

Figure 4-3. Literature Inventory Tree – Environmental Release and Occupational Exposure for HHCB

View the interactive literature inventory tree in HAWC (accessed March 10, 2026). Data in this figure represents all references obtained from the publicly available databases and gray literature references searches that were included in systematic review as of January 20, 2026. Additional data may be added to the interactive version as they become available.

4.5 General Population, Consumer, and Environmental Exposure

During data screening, EPA followed the process described in Appendix H.4 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) to conduct TIAB and full-text screening for HHCB literature search results, as guided by the PECO statement. PECO stands for **P**opulation, **E**xposure, **C**omparator or Scenario, and **O**utcomes for Exposure Concentration or Dose. The same PECO statement was used during TIAB and full-text screening for references considered for the evaluation of general population, consumer, and environmental exposure information for HHCB. TIAB screening was performed using SWIFT Active-Screener. Figure 4-4 presents the number of references that report general population, consumer, and environmental exposure data that passed PECO screening criteria at TIAB and full-text screening.

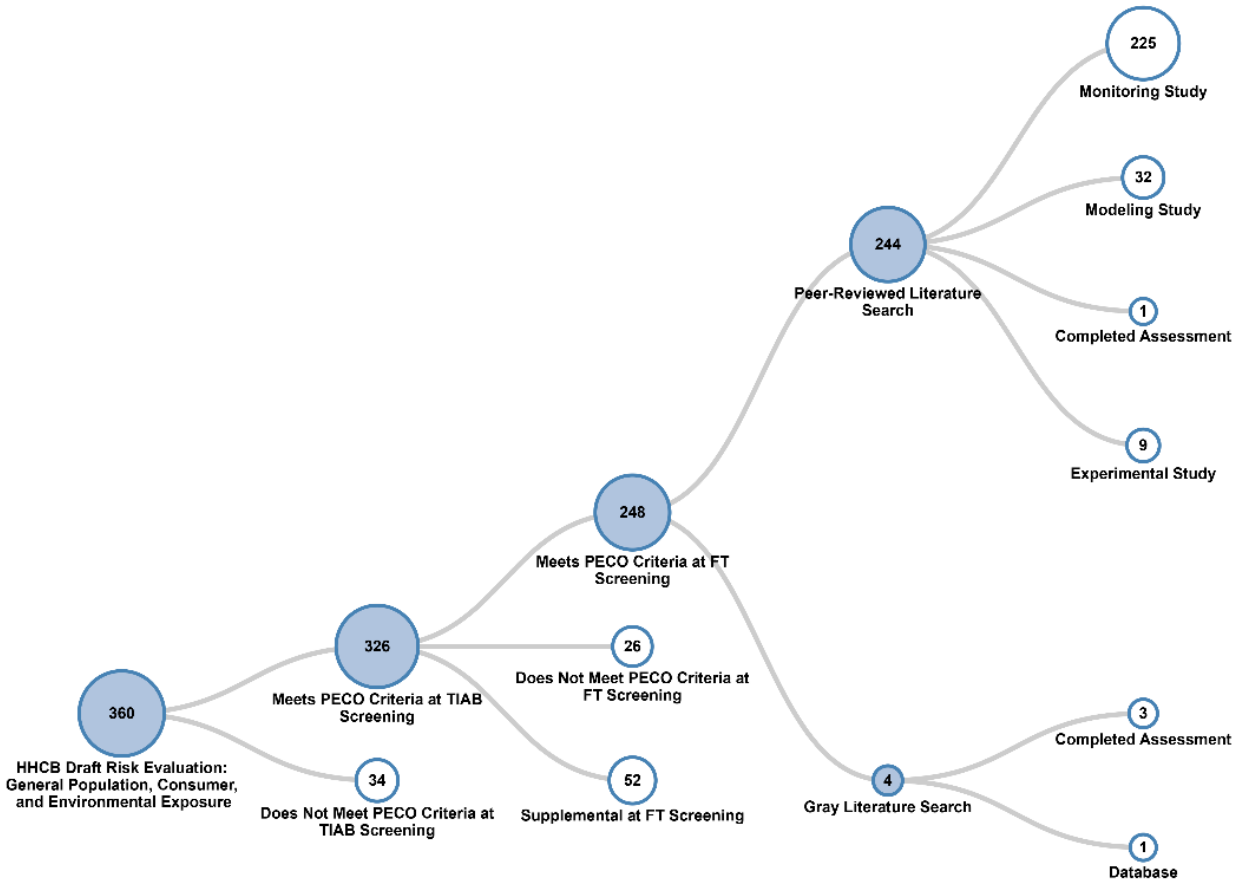

Figure 4-4. Literature Inventory Tree – General Population, Consumer, and Environmental Exposure Search Results for HHCB

View the interactive literature inventory tree in HAWC (accessed March 10, 2026). Data in this figure represent all references obtained from the publicly available databases and gray literature references searches that were included in systematic review as of January 9, 2026. Additional data may be added to the interactive version as they become available.

4.6 Environmental and Human Health Hazard

During data screening, EPA followed the process described in Section 4.2.5 and Appendix H .5, specifically Appendix H.5.5, of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), to conduct TIAB and full-text screening for HHCB literature search results, as guided by the PECO statement. The same PECO statement was used to screen references identified both in the initial search in September 2019 and the update search in May 2025. Also, the same PECO statement was used during

TIAB and full-text screening for references considered for the evaluation of environmental and human health hazard resulting from exposure to HHCB. To screen references from the initial literature search conducted for HHCB in September 2019, EPA utilized machine learning to help prioritize reference screening in SWIFT-Active-Screener for TIAB screening and then used DistillerSR for full-text screening references that either met the PECO screening criteria during TIAB screening or if it was unclear to EPA whether the reference would meet the PECO screening criteria based on the information available in the title and abstract. To screen references from the updated literature search conducted for HHCB in May 2025, EPA utilized DistillerSR for both TIAB and full-text screening.

The PECO statement provided in Appendix H.5.5 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) was used during TIAB and full-text screening for HHCB. Figure 4-5 presents the number of references that report environmental and human health hazard data that met PECO screening criteria at TIAB and full-text screening for HHCB.

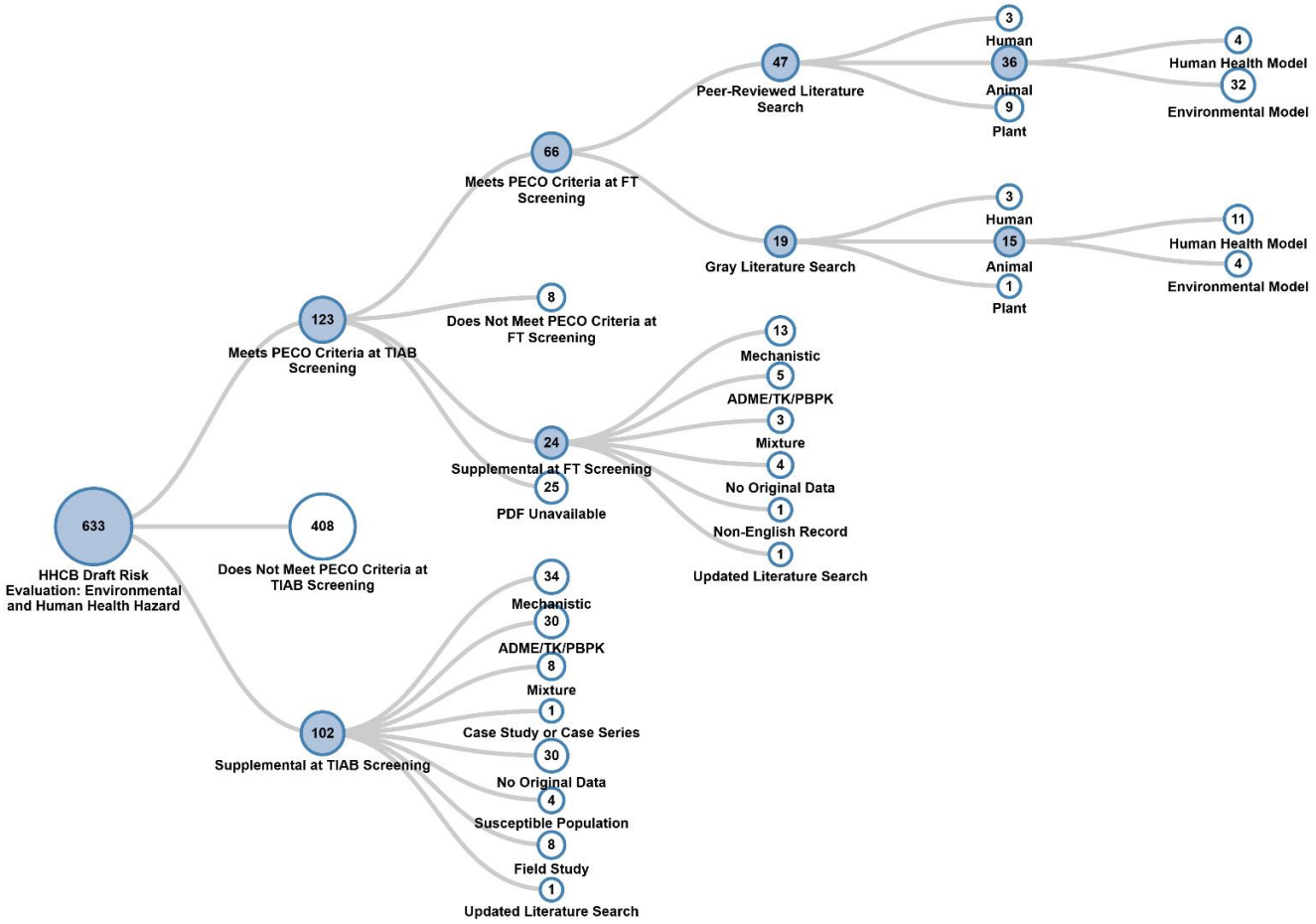

Figure 4-5. Literature Inventory Tree – Environmental and Human Health Hazard for HHCB
View the interactive literature inventory tree in HAWC (accessed March 10, 2026). Data in this figure represents all references obtained from the publicly available databases and gray literature references searches that were included in systematic review as of February 6, 2026. Additional data may be added to the interactive version as they become available.

Of the new additional sources of data that EPA identified for HHCB from the update to the peer-reviewed literature search for environmental and human health hazard, 172 references went through TIAB screening. Of these 172 references, 90 references met the PECO screening criteria during TIAB screening or were unclear to EPA whether the reference met the PECO screening criteria and moved to

full-text screening. At the completion of full-text screening, of these 90 references EPA identified 1 hazard study (HERO ID 7506901) that met the full-text screening criteria and moved to the data evaluation and extraction step of the systematic review process. HERO ID 7506901 was tagged during full-text screening as an animal, environmental model study.

4.7 Dermal Absorption

EPA developed a PECO statement (Table 4-1) to conduct both TIAB and full-text screening of references considered for the evaluation of dermal absorption resulting from HHCB exposure. EPA used Table 4-2 to identify supplemental studies that may also inform dermal absorption and exposure for HHCB. Each reference was manually screened by two reviewers at the TIAB and full-text screening steps or only at full-text, as relevant for the type of data source (peer vs. gray). Figure 4-6 presents the outcome of applying the search strings presented in Section 3.7.1 and the PECO screening criteria below.

Table 4-1. PECA Statement for Dermal Exposure References for HHCB

PECO Element	Evidence
P	Tests of the single toxicants on *ex vivo* tissues (including permeation and retention studies) or on live, whole, taxonomically verifiable organisms are included. **Human:** Any population and life stage (occupational or general population, including children and other sensitive populations). **Animal:** All human health models, including (but not limited to) rat, mouse, rabbit, dog, hamster, guinea pig, cat, non-human primate, and pig. **Supplemental:** Tests using 3D human skin equivalent/reconstructed tissue models (*e.g.,* EpiDerm, EPISKIN) or any other *in vitro* systems are considered supplemental.
E	**Human and Animal:** Any quantified dermal exposure to 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB; CASRN 1222-05-5) either alone or in a vehicle or relevant matrix associated with the conditions of use, including exposure that occurs *in vivo* or *ex vivo* for any duration. No isomers were included for HHCB. Studies are included only if exposure is intentional and quantified. If exposure is not intentional and is not experimentally controlled, the study is excluded. For example, studies of absorption in workers will be excluded, even if exposure has been quantified. Studies assessing exposures to mixtures (*i.e.,* containing substances other than a vehicle) will be included only if they also contain an exposure or treatment group assessing the chemical of interest alone or in aqueous solution. **Supplemental:** *In vitro* exposures and/or studies in which exposure occurs only to a mixture containing one or more of the chemicals of interest.
C	**Human and Animal:** Any or no comparison group
O	**Human and Animal:** Any quantitative assessment of the rate or extent of dermal absorption of the substance. Measurements may include the amount of substance that has passed through the skin, or was retained in the skin, distributed within the organism (*e.g.,* blood and tissue concentrations), and/or excreted by the organism (*e.g.,* through urine, feces, or expired air). Absorption may be measured directly (by chemical analysis for the substance and/or its metabolites) or indirectly (*e.g.,* measurement of radioactivity if using a radio-labelled test substance). Absorption may be quantified via determination of percent absorption, dermal/penetrative flux rate, or dermal penetration coefficient (K_p).

Table 4-2. Major Categories of "Potentially Relevant Supplemental Material"

Category	Evidence
In vitro studies	Tests using 3D human skin equivalent/reconstructed tissue models (*e.g.,* EpiDerm, EPISKIN) or any other *in vitro* systems
Mixture studies	Experimental mixture studies that are not considered PECO-relevant because they do not contain an exposure or treatment group assessing only the chemical of interest, but that otherwise meet PECO criteria
Non-English records	Non-English records that appear to meet PECO criteria
Records with no original data	Records that do not contain original data, such as other agency assessments, informative scientific literature reviews, editorials, or commentaries that would otherwise meet PECO criteria. This also includes studies of dermal exposure/risk/modeling that may cite dermal absorption studies.
Conference abstracts	Records that would otherwise meet PECO criteria, but do not contain sufficient documentation to support study evaluation and data extraction

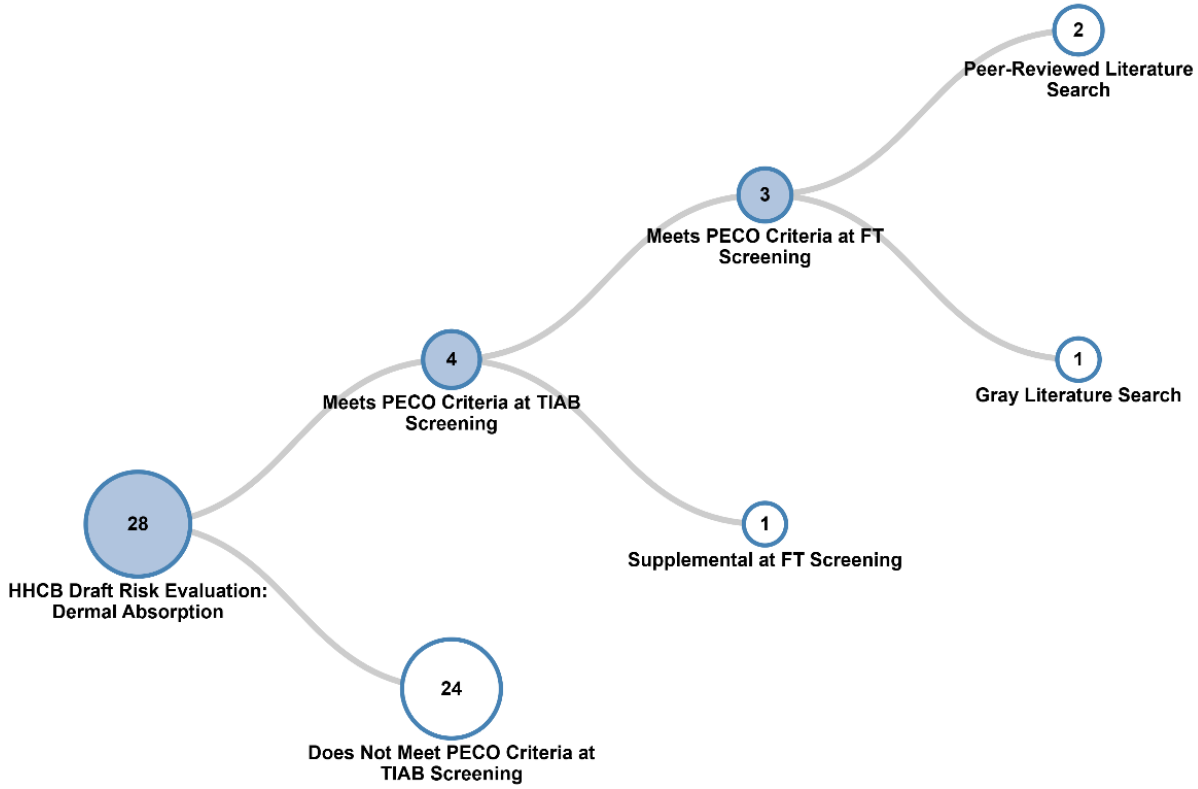

Figure 4-6. Literature Inventory Tree – Dermal Absorption for HHCB
View the interactive literature inventory tree in HAWC (accessed March 10, 2026). Data in this figure represents all references obtained from the publicly available databases and gray literature references searches that were included in systematic review for HHCB as of January 21, 2025. Additional data may be added to the interactive version as they become available.

5 DATA EVALUATION AND DATA EXTRACTION

Data evaluation and extraction were conducted as described in Sections 5 and 6 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Data evaluation is the systematic review step in which EPA assesses quality of the individual data sources using the evaluation strategies and criteria for each discipline (*e.g.,* physical and chemical property data; fate and transport data; occupational exposure and environmental release data; general population, consumer, and environmental exposure data; environmental hazard; human health hazard) or sub-discipline (*e.g.,* animal toxicity or epidemiology). The data quality evaluation method uses a structured framework with predefined criteria for each type of data/information source. Data extraction is the systematic review step in which EPA uses structured forms or templates to extract quantitative and qualitative data and information from references that meet screening criteria. The overall goal is to provide transparency, consistency, and as much objectivity as possible to the data quality evaluation and extraction processes along with meeting the TSCA scientific standards in section 26(h).

References that meet screening criteria following full-text screening will generally proceed to data quality evaluation and extraction steps, however one clarification to the procedures outlined in Section 6 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) is that in situations where EPA is unable to extract data/information from sources that meet screening criteria (*e.g.,* formatting prohibits accurate extraction), that source may not have extracted data to present in the risk evaluation or respective supplemental documents. The systematic review supplemental files that contain results from the data quality evaluation and extraction systematic review steps may use updated templates from those that were provided in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) because the purpose of these supplemental documents is to accommodate the data needs for each respective risk evaluation. The following sections describe the data quality and extraction process followed by each discipline or sub-discipline to address various information needs for the *Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026m) and any clarifications or updates regarding these systematic review steps as described in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021).

An additional clarification relates to falsified information. During the search for reasonably available information, EPA may identify and screen studies conducted by laboratories that had provided falsified information to the EPA (*e.g.,* studies conducted by Industrial Biotest Labs (IBT) between the years of 1965 and 1985). If such studies were identified and considered for TSCA section 6 risk evaluations, EPA did not conduct data quality evaluation and data extraction for these references because the reported information regarding the study methodologies, results, and conclusions is not reputable and accurate. This is the systematic practice related to falsified information, but for clarification, EPA did not identify studies with falsified information for HHCB.

An important update to the data quality evaluation and data extraction process as outlined in Section 5 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) is that in unique circumstances EPA might use data evaluation reports (DERs) instead of using the data quality evaluation and extraction method described in Section 5 of the 2021 Draft Systematic Review Protocol. If a DER is used to evaluate studies for risk evaluations under TSCA, EPA will only use it to evaluate and extract data for human health hazard studies. These DERs use a structured consistent framework with predefined criteria to evaluate studies under TSCA. While the use of DERs as part of the systematic review process under TSCA is new, EPA has used DERs to evaluate studies for decades in the Office of Pesticide Programs (OPP). Specifically, EPA's OPP and the Canadian Pest Management Regulatory Agency (PMRA) developed standard data evaluation templates. The templates have been in use since 2002 for writing data evaluation records (DERs) of studies submitted under the U.S. data requirements for

pesticide registration (40 CFR, Part 158) and the Canadian data codes (DACOs). A list of the templates used to write DERs can be found here: https://www.epa.gov/pesticide-registration/oecd-data-evaluation-record-templates (accessed March 10, 2026). The rationale for when EPA uses a DER to evaluate and extract data for human health hazard studies under TSCA is described in Section 5.5.2.

5.1 Physical and Chemical Properties

As described in the 2021 Draft Systematic Review Protocol, evaluation and extraction followed the steps outlined in Sections 5, 6, and 6.1 (U.S. EPA, 2021). The data quality criteria for physical and chemical property data are summarized in Appendix K of the 2021 Draft Systematic Review Protocol. The *Draft Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)*(U.S. EPA, 2026e) provides details of the data extracted and evaluated, including metric ratings and the overall study quality determination for each data source.

5.2 Environmental Fate and Transport Properties

As described in the 2021 Draft Systematic Review Protocol, evaluation and extraction followed the steps outlined in Sections 5, 6, and 6.2 (U.S. EPA, 2021). The data quality criteria for environmental fate data are summarized in Appendix L of the draft protocol. Appendix L.4 describes how the overall quality of fate data or information were weighted according to an ordinal system corresponding to *High (1)*, *Medium (2)*, or *Low (3)* to quantitatively or qualitatively support the risk evaluations. EPA does not plan to use data rated as *Uninformative (4).* Table_Apx L4 illustrates the possible quality rankings across the selected metrics for environmental fate data with examples in Table_Apx L5, Table_Apx L6 and Table_Apx L7 (U.S. EPA, 2021). Specific fate data quality ranking quality criteria are in Table_Apx L8. The *Draft Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)*(U.S. EPA, 2026e) provides details of the data extracted and evaluated, including metric rating and the overall study quality determination for each data source.

5.3 Environmental Release and Occupational Exposure

As described in the 2021 Draft Systematic Review Protocol, evaluation and extraction followed the steps outlined in Sections 5, 6, and 6.2 (U.S. EPA, 2021). The data quality criteria for environmental release and occupational exposure data are summarized in Appendix M of the draft protocol (U.S. EPA, 2021). The *Draft Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026d) details the data extracted and evaluated, including metric rating and the overall study quality determination for each data source.

5.4 General Population, Consumer, and Environmental Exposure

As described in the 2021 Draft Systematic Review Protocol, data quality evaluation and extraction generally followed the steps outlined in Section 5 and 6 (U.S. EPA, 2021). However, a few updates were made to the data quality evaluation metrics for some evidence streams (*i.e.,* study types) since the metrics were published in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Most of the changes were editorial or minor clarifications, including the standardization of some metrics that apply to multiple evidence streams, where appropriate. For example, in the quality assurance/quality control (QA/QC) metric for evaluating monitoring and experimental evidence streams, the acronym QA/QC was defined and replaced all references to quality assurance and quality control when occurring separately or together, and the term “QA/QC techniques” was changed to “QA/QC measures,” which already appeared in the metrics.

A few metrics Applicable to multiple evidence streams were slightly modified to better fit some of the unique situations that frequently arise for a certain type of evidence stream (*e.g.,* databases). For example, some metrics were updated to clarify the intent of the metric and better account for variation in types of evidence included in one grouping (*e.g.,* experiments involving chamber studies vs. product concentration assessments). The domains did not change, however see below for the changes and updates made to the data evaluation metrics for the respective evidence types (*i.e.,* monitoring, experimental studies and databases) as presented in Section 5.4.1. No changes were made to the data evaluation metrics for modeling data, as described in Appendix N.6.2, or to the data evaluation metrics for completed exposure assessments and risk characterizations, as described in Appendix N.6.7 in the 2021 Draft Systematic Review Protocol, respectively (U.S. EPA, 2021). Data quality evaluations for references that met PECO screening criteria are included in the *Draft Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026g), referred to hereafter as the "HHCB Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure."

Data extraction of general population, consumer, and environmental exposure data and information was conducted as described in Section 6 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). However, with respect to information stored within databases, if EPA has access to the data tables, EPA does not conduct a separate data extraction because the data are more accessible and have additional context in the original database format. Data present in the database when the database underwent full-text screening are available in the HERO database (CDC, 2022; U.S. EPA, 2022a; U.S. EPA et al., 2022; QuanTech, 2021), along with the date the data were downloaded. If a reference (*e.g.,* peer-reviewed reference) presents data from a database that did not undergo systematic review directly (*e.g.,* a foreign database that is not publicly accessible), the data would be extracted from the reference to the extent possible; this did not apply to references that underwent systematic review for this chemical.

As mentioned above in Section 5, references may not undergo data extraction, regardless of the overall quality determination, if they contain no extractable data points (*e.g.,* values are contained in a non-digitizable figure or are representative of unspecified media or treatment processes). On the other hand, there are references that have many reported endpoints that meet PECO screening criteria for a respective chemical risk evaluation, making it difficult to include all the data in the chemical-specific data extraction supplemental file. When a reference meets PECO screening criteria, the reference receives a data quality evaluation, and the data in the reference are still considered in the risk evaluation, whether or not the included data are extracted in DistillerSR and appear among the chemical-specific extractions in the HHCB Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure (U.S. EPA, 2026g). In addition, there may be other reasons that EPA decides not to extract all the data from a reference that undergoes data evaluation; EPA extracts the data that are most relevant, given the needs of the assessment. As seen in Figure 4-5, the extracted HHCB data are from targeted evaluated references that have an OQD of High assuming that such studies would be distinctly supportive to the HHCB exposure assessment. The extracted data provide a high level of confidence for characterizing general population, consumer, and environmental exposure and for meeting assessment needs. This constitutes an update to Section 6 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Extraction forms, templates, and decisions are tailored to fit the data extraction needs for each risk evaluation.

The types of fields extracted vary by evidence stream and generally followed Section 6.3 of the 2021 Draft Systematic Review Protocol with regard to the data characteristics captured (U.S. EPA, 2021). Examples of types of data extracted and the extraction formats for the evidence streams identified

through systematic review to evaluate environmental, general population, and consumer exposure data are listed in the extraction tables provided in the HHCB Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure (U.S. EPA, 2026g).

5.4.1 Data Quality Evaluation Metric Updates

The data evaluation metrics for the monitoring, experimental, and database evidence streams, are presented below in Table 5-1, Table 5-2, and Table 5-3, respectively. Each table shows which data evaluation metrics changed since the publication of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Other data quality criteria for studies on consumer, general population, and environmental exposure appear in Appendix N of the 2021 draft protocol (U.S. EPA, 2021). For the modeling, completed exposure assessments, and risk characterization evidence streams, there were no changes made to the data evaluation metrics since the 2021 Draft Systematic Review Protocol was published. The criteria for modeling studies appear in Table_Apx N-9 of the 2021 draft protocol, and criteria for completed exposure assessments and risk characterizations appear in Table_Apx N-19. In some cases, references can meet the criteria for two exposure evidence streams, and they can also be reviewed and meet criteria for other disciplines. Upon review, each study is evaluated and extracted using the criteria for the most appropriate and Applicable evidence streams given the information therein. In order to make it easier for the reader to see changes made to the data evaluation metrics, the following conventions are used: text inserted is underlined, and text deleted is in ~~strikethrough~~.

Table 5-1. Updated Data Quality Evaluation Criteria for Monitoring Data Sources

Data Quality Rating	Description
Domain 1. Reliability	
Metric 1. Sampling methodology	
High	Samples were collected according to publicly available SOPs that are scientifically sound and widely accepted (*i.e.,* from a source generally ~~using~~ known to use sound methods and/or approaches) for the chemical and media of interest. Example SOPs include U.S. Geological Survey (USGS') "National Field Manual for the Collection of Water-Quality Data," EPA's "Ambient Air Sampling" (SESDPROC-303-R5), etc. OR The sampling protocol used was not a publicly available SOP from a source generally known to use ~~using~~ sound methods and/or approaches, but the sampling methodology is clear, appropriate (*i.e.,* scientifically sound), and similar to widely accepted protocols for the chemical and media of interest. All pertinent sampling information is provided in the data source or companion source. Examples include: • sampling equipment • sampling procedures/regimen • sample storage conditions/duration • performance/calibration of sampler • study site characteristics • matrix characteristics

Data Quality Rating	Description
Medium	Sampling methodology is discussed in the data source or companion source and is generally appropriate (*i.e.,* scientifically sound) for the chemical and media of interest; however, **one or more pieces of sampling information is not described.** The missing information is unlikely to have a substantial impact on results. OR Standards, methods, protocols, or test guidelines may not be widely accepted, but a successful validation study for the new/unconventional procedure was conducted prior to the sampling event and is consistent with sound scientific theory and/or accepted approaches. Or a review of information indicates the methodology is acceptable and differences in methods are not expected to lead to lower quality data.
Low	Sampling methodology is only briefly discussed; therefore, **most sampling information is missing** and likely to have a substantial impact on results. AND/OR The sampling methodology **does not represent best sampling methods, protocols, or guidelines** for the chemical and media of interest (*e.g.,* outdated [but still valid] sampling equipment or procedures, long storage durations). AND/OR There are **some inconsistencies** in the reporting of sampling information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) that led to a low confidence in the sampling methodology used.
Critically Deficient	The sampling methodology is not discussed in the data source or companion source. AND/OR Sampling methodology is not scientifically sound or is not consistent with widely accepted methods/approaches for the chemical and media being analyzed (*e.g.,* inappropriate sampling equipment, improper storage conditions). AND/OR There are **numerous inconsistencies** in the reporting of sampling information, resulting in high uncertainty in the sampling methods used.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2. Analytical methodology	

Data Quality Rating	Description
High	Samples were analyzed according to publicly available analytical methods that are scientifically sound and widely accepted (*i.e.,* from a source generally ~~using~~ known to use sound methods and/or approaches) and are appropriate for the chemical and media of interest. Examples include EPA SW-846 Methods, NIOSH Manual of Analytical Methods 5th Edition, etc. OR The analytical method used was not a publicly available method from a source generally ~~using~~ known to use sound methods and/or approaches, but the methodology is clear and appropriate (*i.e.,* scientifically sound) and similar to widely accepted protocols for the chemical and media of interest. All pertinent sampling information is provided in the data source or companion source. Examples include: • extraction method • analytical instrumentation (required) • instrument calibration • limit of quantitation (LOQ), LOD, detection limits, and/or reporting limits • recovery samples • biomarker used (if Applicable) • matrix-adjustment method (*i.e.,* creatinine, lipid, moisture)
Medium	Analytical methodology is discussed in detail and is clear and appropriate (*i.e.,* scientifically sound) for the chemical and media of interest; however, **one or more pieces of analytical information is not described**. The missing information is unlikely to have a substantial impact on results. AND/OR The analytical **method may not be standard/widely accepted, but a method validation study was conducted** prior to sample analysis and is expected to be consistent with sound scientific theory and/or accepted approaches. AND/OR Samples were collected at a site and immediately analyzed using an on-site mobile laboratory, rather than shipped to a stationary laboratory.
Low	Analytical methodology is only briefly discussed. Analytical instrumentation is provided and consistent with accepted analytical instrumentation/methods. However, **most analytical information is missing** and likely to have a substantial impact on results. AND/OR Analytical method **is not s**tandard/widely accepted, and method validation is limited or not available. AND/OR Samples were analyzed using field screening techniques. AND/OR LOQ, LOD, detection limits, and/or reporting limits not reported. AND/OR There are **some inconsistencies or possible errors** in the reporting of analytical information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) which leads to a lower confidence in the method used.

Data Quality Rating	Description
Critically Deficient	Analytical methodology is not described, **including analytical instrumentation** (*i.e.,* HPLC, GC). AND/OR Analytical methodology is not scientifically appropriate for the chemical and media being analyzed (*e.g.,* method not sensitive enough, not specific to the chemical, out of date). AND/OR There are numerous inconsistencies in the reporting of analytical information, resulting in high uncertainty in the analytical methods used.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 3. Selection of biomarker of exposure	
High	Biomarker in a specified matrix is known to have an accurate and precise quantitative relationship with external exposure, internal dose, or target dose (*e.g.,* previous studies (or the current study) have indicated the biomarker of interest reflects external exposures). AND Biomarker (parent chemical or metabolite) is derived from exposure to the chemical of interest.
Medium	Biomarker in a specified matrix has accurate and precise quantitative relationship with external exposure, internal dose, or target dose. AND Biomarker is derived from multiple parent chemicals, not only the chemical of interest, **but** there is a stated method to apportion the estimate to only the chemical of interest
Low	Biomarker in a specified matrix has accurate and precise quantitative relationship with external exposure, internal dose, or target dose. AND Biomarker is derived from multiple parent chemicals, not only the chemical of interest, **and** there is NOT an accurate method to apportion the estimate to only the chemical of interest. OR Biomarker in a specified matrix is a poor surrogate (low accuracy and precision) for exposure/dose.
Critically Deficient	Not Applicable. A study will not be deemed critically deficient based on the use of biomarker of exposure.
Not Rated/Not Applicable	Metric is not Applicable to the data source.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 2. Representative	
Metric 4. Geographic area	
High	Geographic location(s) is reported, discussed, or referenced.

Data Quality Rating	Description
Medium	Not Applicable. This metric is dichotomous (*i.e.,* high vs. critically deficient).
Low	Not Applicable. This metric is dichotomous (*i.e.,* high vs. critically deficient).
Critically Deficient	Geographic location is not reported, discussed, or referenced.
Not Rated/Not Applicable	
Reviewer's comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 5. Temporality	
High	Timing of sample collection for monitoring data is consistent with current or recent exposures **(within 5 years)** may be expected.
Medium	Timing of sample collection for monitoring data **is less consistent** with current or recent exposures **(>5 to 15 years)** may be expected.
Low	Timing of sample collection for monitoring data is not consistent with when current exposures **(>15 years old)** may be expected and likely to have a substantial impact on results.
Critically Deficient	Timing of sample collection for monitoring data is **not reported, discussed, or referenced.**
Not rated/Not Applicable	
Reviewer's comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 6. Spatial and temporal variability	
High	Sampling approach accurately captures variability of environmental contamination in population/scenario/media of interest based on the heterogeneity/homogeneity and dynamic/static state of the environmental system. For example: • **Large sample size** (*i.e.,* ≥10 or more samples for a single scenario). • Use of replicate samples. • Use of systematic or continuous monitoring methods. • Sampling over a sufficient period of time to characterize trends. • For urine, 24-hour samples are collected (vs. first morning voids or spot). • For biomonitoring studies, the timing of sample collected is appropriate based on chemical properties (*e.g.,* half-life), the pharmacokinetics of the chemical (*e.g.,* rate of uptake and elimination), and when the exposure event occurred.
Medium	Sampling approach likely captures variability of environmental contamination in population/scenario/media of interest based on the heterogeneity/homogeneity and dynamic/static state of the environmental system. Some uncertainty may exist, but it is unlikely to have a substantial impact on results. For example: • **Moderate sample size** (*i.e.,* 5–10 samples for a single scenario), or • Use of judgmental (non-statistical) sampling approach, or • No replicate samples. • For urine, first morning voids or pooled spot samples.

Data Quality Rating	Description
Low	Sampling approach poorly captures variability of environmental contamination in population/scenario/media of interest. For example: • **Small sample size** (*i.e.,* <5 samples), or • Use of haphazard sampling approach, or • No replicate samples, or • Grab or spot samples in single space or time, or • Random sampling that does not include all periods of time or locations, or • For urine, un-pooled spot samples.
Critically Deficient	Sample size is not reported. **Single sample** collected per data set. For biomonitoring studies, the timing of sample collected is not appropriate based on chemical properties (*e.g.,* half-life), the pharmacokinetics of the chemical (*e.g.,* rate of uptake and elimination), and when the exposure event occurred.
Not Rated/Not Applicable	
Reviewer's comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 7. Exposure scenario	
High	The data closely represent relevant exposure scenario (*i.e.,* the population/scenario/media of interest). Examples include: • amount and type of chemical/product used • source of exposure • method of application or by-stander exposure • use of exposure controls • microenvironment (location, time, climate)
Medium	The data likely represent the relevant exposure scenario (*i.e.,* population/scenario/media of interest). **One or more key pieces of information may not be described** but the deficiencies are unlikely to have a substantial impact on the characterization of the exposure scenario. AND/OR If surrogate data, activities seem similar to the activities within scope.
Low	The data lack multiple key pieces of information, and the deficiencies are likely to have a substantial impact on the characterization of the exposure scenario. AND/OR There are **some inconsistencies or possible errors** in the reporting of scenario information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) which leads to a lower confidence in the scenario assessed. AND/OR If surrogate data, activities have lesser similarity but are still potentially Applicable to the activities within scope.
Critically Deficient	If reported, the exposure scenario discussed in the monitored study does not represent the exposure scenario of interest for the chemical.
Not rated/Not Applicable	

Data Quality Rating	Description
Reviewer's comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Accessibility/clarity	
Metric 8. Reporting of results	
High	Supplementary or raw data (*i.e.,* individual data points) are reported, allowing summary statistics to be calculated or reproduced. AND Summary statistics are detailed and complete. Example parameters include: • Description of data set summarized (*i.e.,* location, population, dates, etc.) • Range of concentrations or percentiles • Number of samples in data set • Frequency of detection • Measure of variation (coefficient of variation [CV], standard deviation) • Measure of central tendency (mean, geometric mean, median) • Test for outliers (if Applicable) AND Both adjusted and unadjusted results are provided (*i.e.,* correction for void completeness in urine biomonitoring, whole-volume or lipid adjusted for blood biomonitoring, wet or dry weight for environmental tissue samples or soil samples) [only if Applicable].
Medium	Supplementary or raw data (*i.e.,* individual data points) are not reported, and therefore summary statistics cannot be reproduced. AND/OR Summary statistics are reported but are missing one or more parameters (see description for high). AND/OR Only adjusted or unadjusted results are provided, but not both [only if Applicable].
Low	Supplementary data are not provided, and summary statistics are missing most parameters (see description for high). AND/OR There are some inconsistencies or errors in the results reported, resulting in low confidence in the results reported (*e.g.,* differences between text and tables in data source, less appropriate statistical methods).
Critically Deficient	There are numerous inconsistencies or errors in the calculation and/or reporting of results, resulting in highly uncertain reported results.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 9. Quality assurance	
High	The study quality assurance/quality control (QA/QC) measures and all pertinent ~~quality assurance~~ QA/QC information is provided in the data source or companion source. Examples include: • Field, laboratory, and/or storage recoveries. • Field and laboratory control samples. • Baseline (pre-exposure) samples.

Data Quality Rating	Description
	• Biomarker stability • Completeness of sample (*i.e.,* creatinine, specific gravity, osmolality for urine samples) AND No QA/QC ~~quality control~~ issues were identified, or any identified issues were minor and adequately addressed (*i.e.,* correction for low recoveries, correction for completeness).
Medium	The study applied and documented ~~quality assurance/quality control~~ QA/QC measures; however, **one or more pieces of QA/QC information is not described.** Missing information is unlikely to have a substantial impact on results. AND No QA/QC ~~quality control~~ issues were identified, or any identified issues were minor and addressed (*i.e.,* correction for low recoveries, correction for completeness).
Low	QA/QC measures ~~Quality assurance/quality control techniques~~ and results were not directly discussed but are implied through the study's use of standard field and laboratory protocols. AND/OR Deficiencies were noted in ~~quality assurance/quality control~~ QA/QC measures that are likely to have a substantial impact on results. AND/OR There are some inconsistencies in the ~~quality assurance~~ QA/QC measures reported, resulting in low confidence in the QA/QC ~~quality assurance/control~~ measures taken and results (*e.g.,* differences between text and tables in data source).
Critically Deficient	QA/QC issues have been identified which significantly interfere with the overall reliability of the study.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Variability and uncertainty	
Metric 10. Variability and uncertainty	
High	The study characterizes variability in the population/media studied. AND Key uncertainties, limitations, and data gaps have been identified. AND The uncertainties are minimal and have been characterized.
Medium	The study has limited characterization of variability in the population/media studied. AND/OR The study has limited discussion of key uncertainties, limitations, and data gaps. AND/OR Multiple uncertainties have been identified but are unlikely to have a substantial impact on results.
Low	The characterization of variability is absent. AND/OR Key uncertainties, limitations, and data gaps are not discussed. AND/OR

Data Quality Rating	Description
	Uncertainties identified may have a substantial impact on the exposure the exposure assessment
Critically Deficient	Estimates are highly uncertain based on characterization of variability and uncertainty.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

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Data Quality Rating	Metric Description
Domain 1. Reliability	
Metric 1. Sampling methodology and conditions	
High	Samples were collected according to publicly available SOPs, methods, protocols, or test guidelines that are scientifically sound and widely accepted from a source generally known to use sound methods and/or approaches such as EPA, NIST, American Society for Testing and Materials, ISO, and ACGIH. OR The sampling protocol used was not a publicly available SOP from a source generally known to use sound methods and/or approaches, but the sampling methodology is clear, appropriate (*i.e.,* scientifically sound), and similar to widely accepted protocols for the chemical and media of interest. All pertinent sampling information is provided in the data source or companion source. Examples include: • sampling conditions (*e.g.,* temperature, humidity) • sampling equipment and procedures • sample storage conditions/duration • performance/calibration of sampler
Medium	Sampling methodology is discussed in the data source or companion source and is generally appropriate (*i.e.,* scientifically sound) for the chemical and media of interest, however, one or more pieces of sampling information is not described. The missing information is unlikely to have a substantial impact on results. OR Standards, methods, protocols, or test guidelines may not be widely accepted, but a successful validation study for the new/unconventional procedure was conducted prior to the sampling event and is consistent with sound scientific theory and/or accepted approaches.
Low	Sampling methodology is only briefly discussed. Therefore, most sampling information is missing and likely to have a substantial impact on results. AND/OR The sampling methodology does not represent best sampling methods, protocols, or guidelines for the chemical and media of interest (*e.g.,* outdated (but still valid) sampling equipment or procedures, long storage durations). AND/OR There are some inconsistencies in the reporting of sampling information (*e.g.,* differences between text and tables in data source, differences between standard method

Data Quality Rating	Metric Description
	and actual procedures reported to have been used, etc.) which lead to a low confidence in the sampling methodology used.
Critically Deficient	The sampling methodology is not discussed in the data source or companion source. AND/OR Sampling methodology is not scientifically sound or is not consistent with widely accepted methods/approaches for the chemical and media being analyzed (*e.g.,* inappropriate sampling equipment, improper storage conditions). AND/OR There are numerous inconsistencies in the reporting of sampling information, resulting in high uncertainty in the sampling methods used.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2. Analytical methodology	
High	Samples were analyzed according to publicly available analytical methods that are scientifically sound and widely accepted (*i.e.,* from a source generally using sound methods and/or approaches) and are appropriate for the chemical and media of interest. Examples include EPA SW-846 Methods, NIOSH Manual of Analytical Methods 5th Edition, etc. OR The analytical method used was not a publicly available method from a source generally known to use sound methods and/or approaches, but the methodology is clear and appropriate (*i.e.,* scientifically sound) and similar to widely accepted protocols for the chemical and media of interest. All pertinent analytical ~~sampling~~ information is provided in the data source or companion source. Examples include: • extraction method • analytical instrumentation (required) • instrument calibration • LOQ, LOD, detection limits, and/or reporting limits • recovery samples • biomarker used (if Applicable) • matrix-adjustment method (*i.e.,* creatinine, lipid, moisture)
Medium	Analytical methodology is discussed in detail and is clear and appropriate (*i.e.,* scientifically sound) for the chemical and media of interest; however, one or more pieces of analytical information is not described. The missing information is unlikely to have a substantial impact on results. AND/OR The analytical method may not be standard/widely accepted, but a method validation study was conducted prior to sample analysis and is expected to be consistent with sound scientific theory and/or accepted approaches. AND/OR Samples were collected at a site and immediately analyzed using an on-site mobile laboratory, rather than shipped to a stationary laboratory.
Low	Analytical methodology is only briefly discussed. Analytical instrumentation is provided and consistent with accepted analytical instrumentation/methods. However, most analytical information is missing and likely to have a substantial impact on results.

Data Quality Rating	Metric Description
	AND/OR Analytical method is not standard/widely accepted, and method validation is limited or not available. AND/OR Samples were analyzed using field screening techniques. AND/OR LOQ, LOD, detection limits, and/or reporting limits not reported. AND/OR There are some inconsistencies or possible errors in the reporting of analytical information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) which leads to a lower confidence in the method used.
Critically Deficient	Analytical methodology is not described, including analytical instrumentation (*i.e.,* HPLC, GC). AND/OR Analytical methodology is not scientifically appropriate for the chemical and media being analyzed (*e.g.,* method not sensitive enough, not specific to the chemical, out of date). AND/OR There are numerous inconsistencies in the reporting of analytical information, resulting in high uncertainty in the analytical methods used.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 3. Selection of biomarker of exposure	
High	Biomarker in a specified matrix is known to have an accurate and precise quantitative relationship with external exposure, internal dose, or target dose (*e.g.,* previous studies (or the current study) have indicated the biomarker of interest reflects external exposures). AND Biomarker (parent chemical or metabolite) is derived from exposure to the chemical of interest.
Medium	Biomarker in a specified matrix has accurate and precise quantitative relationship with external exposure, internal dose, or target dose. AND Biomarker is derived from multiple parent chemicals, not only the chemical of interest, **but** there is a stated method to apportion the estimate to only the chemical of interest
Low	Biomarker in a specified matrix has accurate and precise quantitative relationship with external exposure, internal dose, or target dose. AND Biomarker is derived from multiple parent chemicals, not only the chemical of interest, **and** there is NOT a stated method to apportion the estimate to only the chemical of interest. OR Biomarker in a specified matrix is a poor surrogate (low accuracy and precision) for exposure/dose.

Data Quality Rating	Metric Description
Critically Deficient	Not Applicable. A study will not be deemed critically deficient based on the use of biomarker of exposure. ~~Biomarker in a specified matrix is a poor surrogate (low accuracy and precision) for exposure/dose.~~
Not Rated/Not Applicable	Metric is not Applicable to the data source.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 2. Representative	
Metric 4. Testing scenario	
High	Testing conditions closely represent relevant exposure scenarios (*i.e.,* population/scenario/media of interest). Examples include: • amount and type of chemical/product used • source of exposure/test substance • method of application or by-stander exposure • use of exposure controls • microenvironment (location, time, climate, temperature, humidity, pressure, airflow) AND Testing conducted under a broad range of conditions for factors such as temperature, humidity, pressure, airflow, and chemical mass/weight fraction (if appropriate).
Medium	The data likely represent the relevant exposure scenario (*i.e.,* population/scenario/media of interest). One or more key pieces of information may not be described but the deficiencies are unlikely to have a substantial impact on the characterization of the exposure scenario. AND/OR If surrogate data, activities seem similar to the activities within scope.
Low	The data lack multiple key pieces of information, and the deficiencies are likely to have a substantial impact on the characterization of the exposure scenario. AND/OR There are some inconsistencies or possible errors in the reporting of scenario information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) which leads to a lower confidence in the scenario assessed. AND/OR If surrogate data, activities have lesser similarity but are still potentially Applicable to the activities within scope. AND/OR Testing conducted under a single set of conditions, except for experiments to determine a weight fraction or concentration in a product.
Critically Deficient	Testing conditions are not relevant to the exposure scenario of interest for the chemical.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Metric Description
Metric 5. Sample size and variability	
High	Sample size is reported and large enough (*i.e.,* ≥ 10 samples) to be reasonably assured that the samples represent the scenario of interest. AND Replicate tests performed and variability across tests is characterized (if appropriate).
Medium	Sample size is moderate (*i.e.,* 5 to ~~10~~ <10 samples), thus the data are likely to represent the scenario of interest. AND Replicate tests performed and variability across tests is characterized (if appropriate).
Low	Sample size is small (*i.e.,* <5 samples), thus the data are likely to poorly represent the scenario of interest. AND/OR Replicate tests were not performed.
Critically Deficient	Sample size is not reported. AND/OR Single sample collected per data set, except for experiments to determine a weight fraction or concentration in a product. AND/OR For biomonitoring studies, the timing of sample collected is not appropriate based on chemical properties (*e.g.,* half-life), the pharmacokinetics of the chemical (*e.g.,* rate of uptake and elimination), and when the exposure event occurred.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 6. Temporality	
High	Source(s) of tested items appears to be current (within 5 years).
Medium	Source(s) of tested items is less consistent with when current or recent exposures (>5 to 15 years) are expected.
Low	Source(s) of tested items is not consistent with when current or recent exposures (>15 years) are expected or is not identified.
Critically Deficient	Temporality of tested items is not reported, discussed, or referenced.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Accessibility/clarity	
Metric 7. Reporting of results	
High	Supplementary or raw data (*i.e.,* individual data points) are reported, allowing summary statistics to be calculated or reproduced. AND Summary statistics are detailed and complete. Example parameters include: • Description of data set summarized (*i.e.,* location, population, dates, etc.)

Data Quality Rating	Metric Description
	• Range of concentrations or percentiles • Number of samples in data set • Frequency of detection • Measure of variation (CV, standard deviation) • Measure of central tendency (mean, geometric mean, median) • Test for outliers (if Applicable) AND Both adjusted and unadjusted results are provided (*i.e.,* correction for void completeness in urine biomonitoring, whole-volume or lipid adjusted for blood biomonitoring) [only if Applicable].
Medium	Supplementary or raw data (*i.e.,* individual data points) are not reported, and therefore summary statistics cannot be reproduced. AND/OR Summary statistics are reported but are missing one or more parameters (see description for high). AND/OR Only adjusted or unadjusted results are provided, but not both [only if Applicable].
Low	Supplementary data are not provided, and summary statistics are missing most parameters (see description for high). AND/OR There are some inconsistencies or errors in the results reported, resulting in low confidence in the results reported (*e.g.,* differences between text and tables in data source, less appropriate statistical methods).
Critically Deficient	There are numerous inconsistencies or errors in the calculation and/or reporting of results, resulting in highly uncertain reported results.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 8. Quality assurance	
High	The study applied quality assurance/quality control (QA/QC) measures and all pertinent QA/QC ~~quality assurance~~ information is provided in the data source or companion source. Examples include: • Laboratory, and/or storage recoveries • Laboratory control samples • Baseline (pre-exposure) samples • Biomarker stability • Completeness of sample (*i.e.,* creatinine, specific gravity, osmolality for urine samples) AND No QA/QC ~~quality control~~ issues were identified, or any identified issues were minor and adequately addressed (*i.e.,* correction for low recoveries, correction for completeness).
Medium	The study applied and documented ~~quality assurance/quality control~~ QA/QC measures; however, one or more pieces of QA/QC information is not described. Missing information is unlikely to have a substantial impact on results.

Data Quality Rating	Metric Description
	AND No QA/QC ~~quality control~~ issues were identified, or any identified issues were minor and addressed (*i.e.,* correction for low recoveries, correction for completeness).
Low	QA/QC ~~Quality assurance/quality control techniques~~ measures and results were not directly discussed but are ~~can be~~ implied through the study's use of standard field and laboratory protocols. AND/OR Deficiencies were noted in QA/QC ~~quality assurance/quality control~~ measures that are likely to have a substantial impact on results. AND/OR There are some inconsistencies in the QA/QC ~~quality assurance~~ measures reported, resulting in low confidence in the ~~quality assurance/control~~ QA/QC measures taken and results (*e.g.,* differences between text and tables in data source).
Critically Deficient	QA/QC issues have been identified which significantly interfere with the overall reliability of the study.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Variability and uncertainty	
Metric 9. Variability and uncertainty	
High	The study characterizes variability in the population/media studied. AND Key uncertainties, limitations, and data gaps have been identified. AND The uncertainties are minimal and have been characterized.
Medium	The study has limited characterization of variability in the population/media studied. AND/OR The study has limited discussion of key uncertainties, limitations, and data gaps. AND/OR Multiple uncertainties have been identified but are unlikely to have a substantial impact on results.
Low	The characterization of variability is absent. AND/OR Key uncertainties, limitations, and data gaps are not discussed. AND/OR Uncertainties identified may have a substantial impact on ~~the exposure~~ the exposure assessment
Critically Deficient	Estimates are highly uncertain based on characterization of variability and uncertainty.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

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787 **Table 5-3. Updated Data Evaluation Criteria for Database Data**

Data Quality Rating	Description
Domain 1. Reliability	
Metric 1. Sampling methodology	
High	Widely accepted sampling methodologies (*i.e.,* from a source generally known to use ~~using~~ sound methods and/or approaches) were used to generate the data presented in the database. Example SOPs include USGS's "National Field Manual for the Collection of Water-Quality Data," EPA's "Ambient Air Sampling" (SESDPROC-303-R5), etc.
Medium	One or more pieces of sampling methodology information is not described, but missing information is unlikely to have a substantial impact on results. OR The sampling methodologies were consistent with sound scientific theory and/or accepted approaches based on the reported sampling information but may not have followed published procedures from a source generally known to use sound methods and/or approaches.
Low	The sampling methodology was not reported in data source or readily available companion data source.
Critically Deficient	The sampling methodologies used were not appropriate for the chemical/media of interest in the database (*e.g.,* inappropriate sampling equipment, improper storage conditions).
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2. Analytical methodology	
High	Widely accepted analytical methodologies (*i.e.,* from a source generally using sound methods and/or approaches) were used to generate the data presented in the database. Example SOPs include EPA SW-846 Methods, NIOSH Manual of Analytical Methods 5th Edition, etc.
Medium	The analytical methodologies were consistent with sound scientific theory and/or accepted approaches based on the reported analytical information but may not have followed published procedures from a source generally known to use sound methods and/or approaches.
Low	The analytical methodology was not reported in data source or companion data source.
Critically Deficient	The analytical methodologies used were not appropriate for the chemical/media of interest in the database (*e.g.,* method not sensitive enough, not specific to the chemical, out of date).
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Domain 2. Representative	
Metric 3. Geographic area	
High	Geographic location(s) is reported, discussed, or referenced.
Medium	Not Applicable. This metric is dichotomous (*i.e.,* high vs. critically deficient).
Low	Not Applicable. This metric is dichotomous (*i.e.,* high vs. critically deficient).
Critically Deficient	Geographic location is not reported, discussed, or referenced.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 4. Temporal	
High	The data reflect current conditions (within 5 years) AND/OR Database contains robust historical data for spatial and temporal analyses (if Applicable).
Medium	The data are less consistent with current or recent exposures (>5 to 15 years) AND/OR Database contains sufficient historical data for spatial and temporal analyses (if Applicable).
Low	Data are not consistent with when current exposures (>15 years old) may be expected AND/OR Database does not contain enough historical data for spatial and temporal analyses (if Applicable).
Critically Deficient	Timing of sample data is not reported, discussed, or referenced.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 5. Exposure scenario	
High	The data closely represent relevant exposure scenario (*i.e.,* the population/scenario/media of interest). Examples include: • Amount and type of chemical/product used • Source of exposure • Method of application or by-stander exposure • Use of exposure controls • Microenvironment (location, time, climate)
Medium	The data likely represent the relevant exposure scenario (*i.e.,* population/scenario/media of interest). **One or more key pieces of information may not be described** but the deficiencies are unlikely to have a substantial impact on the characterization of the exposure scenario. AND/OR If surrogate data, activities seem similar to the activities within scope.

Data Quality Rating	Description
Low	The data lack multiple key pieces of information and the deficiencies are likely to have a substantial impact on the characterization of the exposure scenario. AND/OR There are **some inconsistencies or possible errors** in the reporting of scenario information (*e.g.,* differences between text and tables in data source, differences between standard method and actual procedures reported to have been used, etc.) which leads to a lower confidence in the scenario assessed. AND/OR If surrogate data, activities have lesser similarity but are still potentially Applicable to the activities within scope.
Critically Deficient	If reported, the exposure scenario discussed in the monitored study does not represent the exposure scenario of interest for the chemical.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Accessibility/clarity	
Metric 6. Availability of database and supporting documents	
High	Database is widely accepted and/or from a source generally known to use sound methods and/or approaches (*e.g.,* raw data from NHANES, STORET).
Medium	The database may not be widely known or accepted (*e.g.,* state-maintained databases), but the database is adequately documented with most or all of the following information: 1. Within the database, metadata is present (sample identifiers, annotations, flags, units, matrix descriptions, etc.) and-data fields are generally clear and defined. 2. A user manual and other supporting documentation is available, or there is sufficient documentation in the data source or companion source. Database quality assurance and data quality control measures are defined and/or a QA/QC protocol was followed.
Low	The database may not be widely known or accepted, and only limited database documentation is available (see the medium rating).
Critically Deficient	No information is provided on the database source or availability to the public.
Not Rated/ Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 7. Reporting of results	
High	The database or information source reporting the analysis of the database data is well organized and understandable by the target audience. AND Summary statistics in the data source are detailed and complete. Example parameters include: • Description of data set summarized (*i.e.,* location, population, dates, etc.) • Range of concentrations or percentiles • Number of samples in data set

Data Quality Rating	Description
	• Frequency of detection • Measure of variation (CV, standard deviation) • Measure of central tendency (mean, geometric mean, median) • Test for outliers (if Applicable)
Medium	The database or information source reporting the analysis of the database data is well organized and understandable by the target audience. AND/OR Summary statistics are missing one or more parameters (see description for high).
Low	The database or information source reporting the analysis of the database data is unclear or not well organized. AND/OR Summary statistics are missing most parameters (see description for high) AND/OR There are some inconsistencies or errors in the results reported, resulting in low confidence in the results reported (*e.g.,* differences between text and tables in data source, less appropriate statistical methods).
Critically Deficient	There are numerous inconsistencies or errors in the calculation and/or reporting of results, resulting in highly uncertain reported results. AND/OR The information source reporting the analysis of the database data is missing key sections or lacks enough organization and clarity to locate and extract necessary information.
Not Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Variability and uncertainty	
Metric 8. Variability and uncertainty	
High	Variability, key uncertainties, limitations, and/or data gaps have been identified. AND/OR The uncertainties are minimal and have been characterized.
Medium	The study has limited discussion of variability, key uncertainties, limitations, and/or data gaps. AND/OR Multiple uncertainties have been identified but are unlikely to have a substantial impact on results.
Low	Variability, key uncertainties, limitations, and data gaps are not discussed. AND/OR Uncertainties identified may have a substantial impact on the exposure the exposure assessment
Critically Deficient	Estimates are highly uncertain based on characterization of variability and uncertainty.
Not Rated/Not Applicable	

Data Quality Rating	Description
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

5.5 Environmental and Human Health Hazard

Details regarding the evaluation and extraction of environmental and human health hazard information from references that met PECO screening criteria are available in Sections 5 and 6.4 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Data quality criteria for environmental studies, animal and *in vitro* toxicity studies and epidemiological studies are available in Appendices P, Q, and R in the 2021 Draft Systematic Review Protocol, respectively (U.S. EPA, 2021). Any updates made to the data quality evaluation and extraction forms for human health hazard information since the 2021 Draft Systematic Review Protocol was published (U.S. EPA, 2021) are described below in Section 5.5.2. The below-listed supplemental documents provide details of the data evaluated and extracted. Data evaluation information for each discipline (*i.e.,* environmental and human health hazard) is contained in separate supplemental documents and includes metric ratings and the overall study quality determination for each data source. On the other hand, data extraction information for both disciplines are contained in a single supplemental document to increase the ease of accessing hazard data that may be relevant for both environmental- and human health-related receptors. One clarification that applies to the data extraction of human health hazard data is that all the data extraction was conducted in DistillerSR. In regard to the environmental hazard data, for references that meet PECO screening criteria at full text screening, the available environmental hazard data were extracted from those references in the ECOTOXicology Knowledgebase (ECOTOX) database and then imported into DistillerSR.

- *Draft Data Quality Evaluation Information for Human Health Hazard Epidemiology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026i)
- *Draft Data Quality Evaluation Information for Environmental Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026f)
- *Draft Data Quality Evaluation Information for Human Health Hazard Animal Toxicology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026h)
- *Draft Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026b)

As stated at the beginning of Section 5 of this chemical-specific systematic review protocol, an important update to the data quality evaluation and extraction process as outlined in Section 5 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) is that in unique circumstances EPA might use DERs to evaluate studies for risk evaluations under TSCA instead of using the data quality evaluation and extraction method described in Section 5 of the 2021 Draft Systematic Review Protocol. The rationale for when EPA has used a DER to evaluate and extract data for human health hazard studies for HHCB is described in Section 5.5.2 of this systematic review protocol. The DERs are available in a separate supplemental document of the risk evaluation for HHCB listed below and provide details of how each study was evaluated and whether the study was acceptable or unacceptable, and guideline or non-guideline.

- *Draft Data Evaluation Records for Human Health Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026a)

5.5.1 Environmental Hazard

As described in Appendix R of the 2021 Draft Systematic Review Protocol, references that met PECO screening criteria at full-text screening underwent data quality evaluation (U.S. EPA, 2021). Likewise, for references that met PECO screening criteria at full-text screening underwent data extraction as described in Section 6.4.1 of the draft protocol. One reference (Ehiguese et al., 2021), identified from the May 2025 updated literature search, met PECO screening criteria but has not yet proceeded to data evaluation and extraction. Data evaluation and data extraction will be completed for this reference prior to release of the final risk evaluation for HHCB. This section describes any updates made to the data quality evaluation and data extraction process for environmental hazard studies since the 2021 Draft Systematic Review Protocol was published.

Data Evaluation and Data Extraction Crosswalk

As per the established systematic review process described in the 2021 Draft Systematic Review Protocol, data extraction is completed for all health outcomes regardless of the OQD a study has received during data quality evaluation (*i.e.,* rating of high, medium, low, or uninformative). Moreover, initial data extractions for environmental hazard are completed outside of DistillerSR by contractors that support ECOTOX, database managed by EPA's ORD. Data extraction QC for HHCB was completed within DistillerSR by experts in environmental hazard.

Since the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) was published, an additional process improvement step has been incorporated into the environmental hazard TSCA systematic review process. EPA staff that perform the data extraction QC need to crosswalk data evaluation forms to data extraction forms to ensure that health outcomes for each experimental condition reported in the study match in both the data evaluation and extraction forms; this step is necessary because the initial data extractions are completed outside of DistillerSR independently of the data evaluation process within DistillerSR. In addition, experts in environmental hazard completing the crosswalk during the data extraction QC need to ensure that the rating for the health outcome in the data evaluation forms is also reported in the data extraction forms.

To maximize efficiency for the completion of the data evaluation and data extraction crosswalk, an external (outside of DistillerSR) automated function has been added. Figure 5-1 summarizes the steps that a study that meets the PECO screening criteria for environmental hazard (green circle) follows until completion of the data evaluation and data extraction crosswalk (gray oval with check mark). The initial data extractions by ECOTOX contractors occur outside of DistillerSR (orange ECOTOX box), and data converted into a JSON (standard file format and data interchange) file are later imported into DistillerSR in preparation for the data extraction QC (second blue square in the red DistillerSR box in Figure 5-1).

The light purple box with the label "External processing" in Figure 5-1 illustrates the steps that occur outside of DistillerSR including the automated crosswalk function (blue square with an asterisk). Specifically, this automated function starts with a data extraction form and compares to the corresponding data evaluation form by first filtering by HERO ID, then filtering by species name, followed by lifestage of the organism, exposure duration, health outcome and chemical type. For each of these filtering levels as the matching function is run, if there is a data evaluation form that corresponds to the data extraction criteria, there is a successful match and the health outcomes in the data extraction form and data evaluation forms are aligned and the rating is also added in the data extraction forms. On the contrary, if there is no data evaluation that corresponds to the data extraction criteria, the automated crosswalk stops, and the outcome of the function is "No Match". If there is no match by the automated function, the crosswalk is completed manually at the final step. Once the automated crosswalk function is complete, the data are converted to a JSON file that is uploaded into DistillerSR. For the final step, the

QCer reviews the data extraction forms for the successful automated matches and completes the crosswalk manually for the forms that did not match (blue square with double asterisks in Figure 5-1), at which point the data evaluation and data extraction crosswalk is complete.

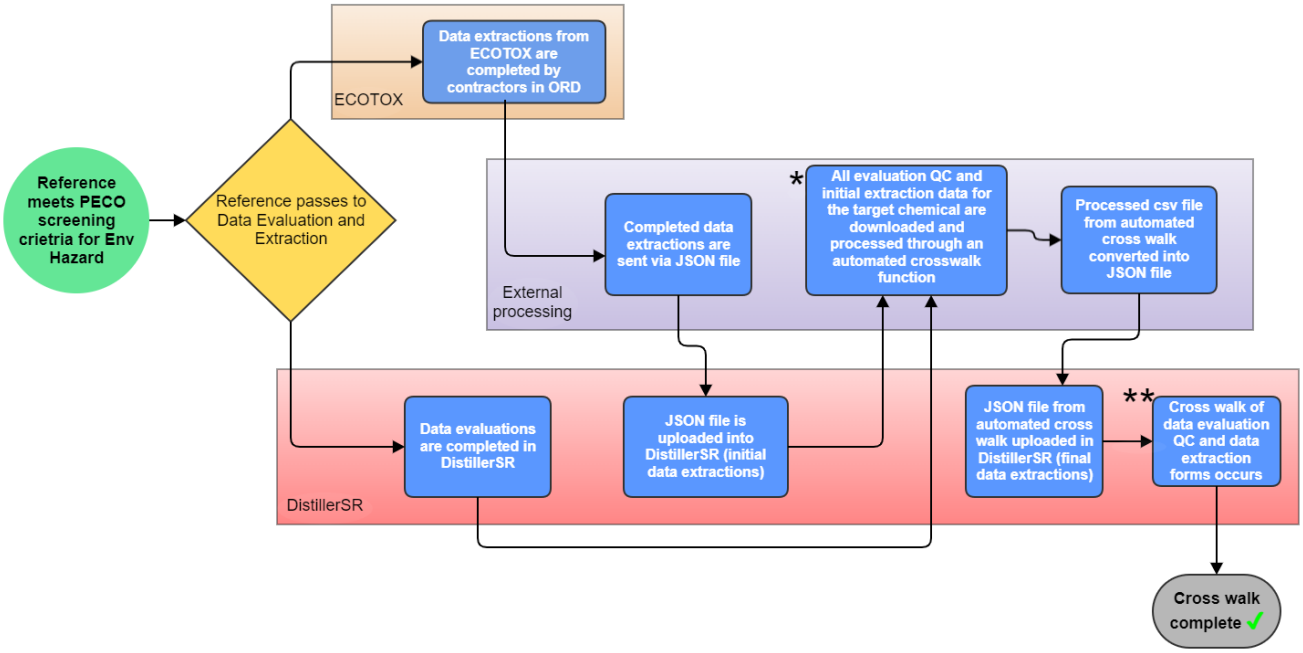

Figure 5-1. Data Evaluation and Data Extraction Crosswalk Workflow for Environmental Hazard

At the completion of the data evaluation and data extraction crosswalk for HHCB, the data extraction information was included in the *Draft Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026b).

5.5.2 Human Health Hazard

As described in Appendices Q and R of the 2021 Draft Systematic Review Protocol, references that met PECO screening criteria at full text screening underwent data quality evaluation (U.S. EPA, 2021). These references also underwent data extraction as described in Section 6.4 of the 2021 Draft Protocol.

Because previous assessments of HHCB used different approaches to considering hazard information and setting PODs, EPA opted to evaluate the full set of studies identified through systematic review rather than narrowing the focus based on the conclusions of previous assessments. There was one exception – EPA did not evaluate or extract animal toxicity studies for routes of exposure other than oral, dermal, or inhalation (*e.g.,* intramuscular, intraperitoneal) even though they met the PECO screening criteria. Any additional clarifications or updates regarding the data quality evaluation or extraction of data from references that met PECO screening criteria at full text screening are discussed further below for epidemiological and animal toxicity studies.

As stated above in Section 5.5, an important update made to the data quality evaluation and extraction framework as described in Section 5 of the of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021) is the use of DERs for evaluating and extracting data for studies that report human health hazard outcomes. The DER contains a study profile documenting study information such as materials, methods, results, applicant's conclusions and the evaluator's conclusions on the quality of the study. Templates to DERs that EPA might use applicable to human health hazard can be found here (accessed March 10,

2026). As part of the systematic process for the completion of DERs, HHCB studies were first evaluated and extracted by an initial reviewer and a QC step was completed by a secondary reviewer.

For HHCB, EPA used DERs to evaluate eight studies (Table 5-4). One of those DERs was used to evaluate a technical report (HERO ID 8785683) that followed OECD Test Guideline 443: Extended One-Generation Reproductive Toxicity Study (EOGRTS) to report hazard outcomes. The EOGRTS test guideline describes a complex, lengthy study and is designed to provide an evaluation of the pre- and postnatal effects of chemicals on development as well as a thorough evaluation of systemic toxicity in pregnant and lactating females and young and adult offspring. Given the study design complexity, EPA used a DER to evaluate data quality. In addition, EPA used DERs to evaluate and extract data from two *in vitro* studies: a dermal absorption study (HERO ID 13006533) and an *in vitro* skin irritation study (HERO ID 8785661). *In vitro* studies could not be evaluated effectively with the data evaluation forms in DistillerSR, EPA's tool and repository to complete data evaluation and extraction. The data evaluation forms currently implemented in DistillerSR are most appropriate for *in vivo* studies, and while data evaluation forms for *in vitro* studies were described in Appendix Q of the 2021 Draft Systematic Review Protocol, they were not implemented in DistillerSR, and EPA opted to proceed with data evaluation and extraction of these *in vitro* studies using DERs. Moreover, these two technical reports followed OEDC test guidelines and because DERs are based on OECD data evaluation record templates, using DERs for data evaluation and extraction of these studies was fitting.

Four other studies were also evaluated and extracted using DERs: a dermal absorption study in human subjects (HERO ID 5428448) and three human repeated insult patch tests (HERO ID 8785146, 8785221, 8785659). While EPA has recently developed a TSCA Intentional Dosing Epidemiology Data Quality Evaluation Form (Table 5-6), the DER format allowed for an alternative method to evaluate the studies. The eight study evaluated using a DER was an *in vivo* uterotrophic assay performed in rodents (HERO ID 5428448) was also evaluated using a DER. HERO ID 5428448 reported data on (1) effects of AHTN and HHCB in ERalpha- and ERbeta-dependent gene transcription assays with Human Embryonal Kidney 293 (HEK293) cells; (2) a uterine weight assay performed in juvenile Balb/c mice where no uterotrophic activity of AHTN and HHCB was noted; and (3) a vitellogenin production assay using carp hepatocytes. The DER was used to evaluate the *in vivo* component of the study *(i.e.,* only the mouse uterotrophic assay).

Table 5-4. List of Studies for HHCB Evaluated Using a Data Evaluation Report (DER) [a]

HERO ID of the Study	Study Title
8785683	Extended 1 generation reproductive toxicity study (including cohorts 1 and F2 - generation of HHCB by the oral route (dietary admixture) in the rat (OECD 443) (sanitized)
13006533	In-vitro human skin penetration of radiolabeled fragrance material HHCB (redacted)
8785661	HHCB/galaxolide undiluted: In vitro Episkin (tm) skin irritation test. (sanitized)
5428448	The systemic exposure to the polycyclic musks, AHTN and HHCB, under conditions of use as fragrance ingredients: Evidence of lack of complete absorption from a skin reservoir
8785146	HHCB no. 24. Repeated insult patch test (sanitized)
8785221	Repeated patch test. Galaxolide. (sanitized)
8785659	Repeated insult patch test galaxolide 50. (sanitized)

HERO ID of the Study	Study Title
1415078	AHTN and HHCB show weak estrogenic—but no uterotrophic activity
[a] To provide transparency, these individual DERs were compiled into a single file that provides details and is available to the public as a supplemental document: *Draft Data Evaluation Records for Human Health Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026a).	

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942 #### 5.5.2.1 Epidemiology Studies

943 As described above in Section 5, all references containing epidemiological information that met PECO
944 screening criteria proceeded to data quality evaluation.
945
946 All epidemiology references that met the PECO screening criteria for HHCB were human intentional
947 dosing studies (or controlled exposure studies). Therefore, the data quality evaluation metrics for
948 observational epidemiology studies were not applicable due to the different study design. Instead, these
949 references were evaluated using a new OPPT data quality evaluation form, which was developed
950 specifically for intentional dosing studies. This form was based on the National Toxicology Program's
951 Office of Health Assessment and Translation (OHAT) risk of bias criteria, with modifications based on
952 assessor feedback. This modified form is referred to as the new TSCA Intentional Dosing Epidemiology
953 Data Quality Evaluation form.
954
955 The first step in developing the new intentional dosing data quality evaluation form was to identify
956 existing data quality evaluation criteria for human intentional dosing studies. Intentional dosing
957 epidemiology studies of potentially hazardous chemicals are relatively rare due to important ethical
958 concerns. Likely due to the rarity of this study type, few entities that conduct systematic review have
959 developed criteria for evaluating the quality of data from intentional dosing studies. For example, the
960 IRIS Handbook includes general recommendations for evaluating controlled exposure studies, but no
961 specific criteria for evaluating this study type. The *Handbook for Conducting a Literature-Based Health*
962 *Assessment Using OHAT Approach for Systematic Review and Evidence Integration* (NTP, 2019) links
963 to a *Risk of Bias Rating Tool for Human and Animal Studies* (NTP, 2015). In contrast to other entities
964 that lack specific criteria, the OHAT Risk of Bias Rating Tool includes criteria for evaluating human
965 controlled trials (HCT). Therefore, these OHAT criteria were determined to be potentially useful for the
966 TSCA data quality evaluation form.
967
968 The next step in determining the relevance of the OHAT criteria consisted of developing an OHAT-
969 TSCA crosswalk to compare OHAT risk of bias rating categories with TSCA metric rating categories.
970 OHAT risk of bias categories are defined on page 36 of the OHAT Handbook (NTP, 2019) and page 4
971 of the OHAT Risk of Bias Rating Tool (NTP, 2015). Both OHAT and TSCA have four ordinal rating
972 categories. Table 5-5 below summarizes the correspondence between these OHAT and TSCA rating
973 categories.
974
975 The OHAT Risk of Bias Tool includes 11 domains formatted as 11 risk of bias questions (NTP, 2015).
976 The OHAT criteria for evaluating each domain are designated for one or more of 6 different study types
977 (1. Experimental Animal, 2. Human Controlled Trial [HCT], 3. Cohort, 4. Case-Control, 5. Cross-
978 Sectional, and 6. Case Series/Case Report). Only the criteria for HCT were considered in development
979 of the new form. Of the 11 OHAT risk of bias questions, the following 7 questions are directly
980 applicable to intentional dosing studies and include OHAT criteria for evaluating human controlled trials
981 (NTP, 2015):

982 1. OHAT Question 1. Was administered dose or exposure level adequately randomized?

2. OHAT Question 2. Was allocation to study groups adequately concealed?
   [There are no criteria for human controlled trials for OHAT Questions 3, 4, and 5.]
3. OHAT Question 6. Were the research personnel and human subjects blinded to the study group during the study?
4. OHAT Question 7. Were outcome data complete without attrition or exclusion from analysis?
5. OHAT Question 8. Can we be confident in the exposure characterization?
6. OHAT Question 9. Can we be confident in the outcome assessment?
7. OHAT Question 10. Were all measured outcomes reported?

These seven questions were grouped into five TSCA domains with a total of seven metrics on the form. The seven metrics were similar to the seven OHAT questions, with some wording changes based on feedback from assessors. The TSCA domains and metrics are provided below:

- TSCA Domain 1. Randomization
  - Metric 1. Was an adequate method used to randomize the administered dose or exposure level?
- TSCA Domain 2. Allocation Concealment and Blinding
  - Metric 2A. Was allocation to study groups adequately concealed until recruitment was complete?
  - Metric 2B. Were the research personnel and human subjects blinded to the study group during the study?
- TSCA Domain 3. Attrition
  - Metric 3. Were outcome data complete without attrition or exclusion from analysis?
- TSCA Domain 4. Exposure Measurement Bias
  - Metric 4. Can we be confident in the exposure characterization?
- TSCA Domain 5. Outcome Assessment
  - Metric 5A. Can we be confident in the outcome assessment?
  - Metric 5B. Selective Reporting: Were all measured outcomes reported?

The OHAT criteria for each metric were included in a draft data quality evaluation form, which was reviewed by the epidemiology experts who conduct TSCA systematic reviews. Questions about the interpretation of criteria were discussed during epidemiology team meetings and modifications to the wording of the criteria were made based on consensus during these discussions. The aims of the wording modifications were to clarify language and to ensure appropriate evaluation of study methods and consistency between different assessors. The data quality evaluation instructions, domains, metrics, and criteria for the new TSCA Intentional Dosing Epidemiology Data Quality Evaluation form are presented below in Table 5-6. The original OHAT wording is in plain text, and modifications are indicated using *italics* for additions and ~~strikethrough~~ for deletions.

The assessment of each of the metrics contributes to an OQD of high, medium, low, or uninformative for the reference. Some references contain multiple health outcomes; therefore, a given reference may have multiple data quality evaluation forms and respective OQDs.

Data from epidemiology studies with statistically significant results underwent data extraction. Other references did not undergo detailed extraction but were considered during evidence integration for the risk evaluation.

Table 5-5. Crosswalk of OHAT Risk of Bias Rating Categories and TSCA Metric Rating Categories

OHAT Ordinal Risk of Bias Rating Category[a]	Description of OHAT Ordinal Rating Category[a]	TSCA Ordinal Metric Rating Category[b]	Description of TSCA Ordinal Rating Category[b]
Definitely low risk of bias ++	There is direct evidence of low risk-of-bias practices (May include specific examples of relevant low risk-of-bias practices)	**High**	No notable deficiencies or concerns are identified related to the metric that are likely to influence results
Probably low risk of bias +	There is indirect evidence of low risk-of-bias practices OR it is deemed that deviations from low risk-of-bias practices for these criteria during the study would not appreciably bias results, including consideration of direction and magnitude of bias	**Medium**	Minor uncertainties or limitations are noted related to the metric that are unlikely to have a substantial impact on results
Probably high risk of bias –	There is indirect evidence of high risk-of-bias practices OR there is insufficient information (*e.g.,* not reported or "NR") provided about relevant risk-of-bias practices	**Low**	Deficiencies or concerns are noted related to the metric that are likely to have a substantial impact on results
Definitely high risk of bias –	There is direct evidence of high risk-of-bias practices (May include specific examples of relevant high risk-of-bias practices)	**Critically Deficient**	Serious flaws are noted related to the metric that consequently make the study unusable for quantitative analyses

[a] Source: National Toxicology Program, OHAT Risk of Bias Rating Tool for Human and Animal Studies (2015) https://ntp.niehs.nih.gov/whatwestudy/assessments/noncancer/riskbias (accessed March 10, 2026) (NTP, 2015).
[b] Source: EPA, *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (2021) (U.S. EPA, 2021).

1032 **Table 5-6. TSCA Intentional Dosing Epidemiology Data Quality Evaluation From**

Data Quality Rating	Criteria Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015) (Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font
	Domain 1. Randomization
Metric 1. Was *an adequate method used to randomize the* administered dose or exposure level ~~adequately randomized~~?	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that subjects were allocated to any study group, including controls, using a method with a random component. Acceptable methods of randomization include: referring to a random number table, using a computer random number generator, coin tossing, shuffling cards or envelopes, throwing dice, or drawing of lots (Higgins and Green 2011). Restricted randomization (*e.g.,* blocked randomization) to ensure particular allocation ratios will be considered *high quality (*low risk of bias*)*. Similarly, stratified randomization and minimization approaches that attempt to minimize imbalance between groups on important prognostic factors (*e.g.,* body weight) will be considered acceptable. *OR* *For intentional dosing studies in which an individual serves as their own control:* *The individuals received different dose levels, such as lower or higher doses at different timepoints or dermal patches on different parts of the body or a vehicle/control patch, and there is direct evidence that this dosing occurred in a randomized order using appropriate methods for randomization.*
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that subjects were allocated to study groups using a method with a random component (*i.e.,* authors state that allocation was random, without description of the method used), OR it is deemed that allocation without a clearly random component during the study would not appreciably bias results *because all participants were sufficiently similar in terms of major potential confounders*. For example, approaches such as biased coin or urn randomization, replacement randomization, mixed randomization, and maximal randomization *should generally be rated Medium if used appropriately but* may require *expert judgement or* consultation with a statistician to determine risk-of-bias rating (Higgins and Green 2011). *OR* *For intentional dosing studies in which an individual serves as their own control:* *All study participants served as their own control and all received the same exposure dose following the same procedures.* *OR* *The individuals received different dose levels, such as lower or higher doses at different timepoints or dermal patches on different parts of the body or a vehicle/control patch, and there is indirect evidence that this dosing occurred in a randomized order.*
Low	*Mark as low quality / Probably High risk of bias if:* There is indirect evidence that subjects were allocated to study groups using a method with a non-random component, *OR there are substantial concerns with the appropriateness of the allocation methods,* OR there is insufficient information provided about how subjects were allocated to study groups (*specify that randomization was not reported or describe the details of why the allocation is potentially non-random in the comments* ~~record "NR" as basis for answer~~). Note: Non-random allocation methods may

Data Quality Rating	Criteria Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015) (Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font
	be systematic but have the potential to allow participants or researchers to anticipate the allocation to study groups. Such "quasi-random" methods include alternation, assignment based on date of birth, case record number, or date of presentation to study (Higgins and Green 2011). *OR* *For intentional dosing studies in which an individual serves as their own control:* *The individuals received different dose levels, such as lower or higher doses at different timepoints or on dermal patches on different parts of the body or a vehicle/control patch, in a non-randomized order.*
Critically deficient	*Mark as critically deficient / Definitely high risk of bias if:* There is direct evidence that subjects were allocated to study groups using a non-random method including judgment of the clinician, preference of the participant, the results of a laboratory test or a series of tests, or availability of the intervention (Higgins and Green 2011).
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*
Domain 2. Allocation concealment and blinding	
Metric 2A. Was allocation to study groups adequately concealed *until recruitment was complete*? *Note:* *For intentional dosing studies in which an individual serves as their own control:* *If the exposure protocol was the same for all participants, then select Medium if "lack of adequate allocation concealment would not appreciably bias results."* *If there were different exposure protocols for different participants, then consider those to be different "groups" and use the existing criteria.*	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that at the time of recruitment *both* the research personnel and subjects did not know what study group subjects were allocated to, and it is unlikely that they could have broken the blinding of allocation until after recruitment was complete and irrevocable. Acceptable methods used to ensure allocation concealment include central allocation (including telephone, web-based and pharmacy-controlled randomization); sequentially numbered drug containers of identical appearance; sequentially numbered, opaque, sealed envelopes; *electronic medical record for "point-of-care" or "clinically integrated" randomized trials;* or equivalent methods.
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that *both* the research personnel and subjects did not know what study group subjects were allocated to and it is unlikely that they could have broken the blinding of allocation until after recruitment was complete and irrevocable, OR it is deemed that lack of adequate allocation concealment would not appreciably bias results.
Low	*Mark as low quality / probably high risk of bias if:* There is indirect evidence that at the time of recruitment it was possible for the research personnel *or* ~~and~~ subjects to know what study group subjects were allocated to, or it is likely that they could have broken the blinding of allocation before recruitment was

Data Quality Rating	Criteria Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015) (Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font
	complete and irrevocable, OR there is insufficient information provided about allocation to study groups (*if there is insufficient information then specify in the comments that relevant information was not reported* ~~record "NR" as basis for answer~~). Note: Inadequate methods include using an open random allocation schedule (*e.g.,* a list of random numbers); assignment envelopes used without appropriate safeguards (*e.g.,* if envelopes were unsealed or non-opaque or not sequentially numbered); alternation or rotation; date of birth; case record number; or any other explicitly unconcealed procedure. For example, if the use of assignment envelopes is described, but it remains unclear whether envelopes were sequentially numbered, opaque and sealed.
Critically deficient	*Mark as critically deficient / definitely high risk of bias if:* There is direct evidence that at the time of recruitment it was *likely* ~~possible~~ for the research personnel *or* ~~and~~ subjects to know what study group subjects were allocated to, or it is likely that they could have broken the blinding of allocation before recruitment was complete and irrevocable.
Not Rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*
Metric 2B. Were the research personnel and human subjects blinded to the study group during the study? *Note:* *For intentional dosing studies in which an individual serves as their own control:* *If the exposure protocol was the same for all participants, then select Medium because "lack of adequate blinding during the study would not appreciably bias results."* *If there were different exposure protocols for different participants, then consider those to be different "groups" and use the existing criteria.*	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that the subjects and research personnel were adequately blinded to study group, and it is unlikely that they could have broken the blinding during the study. Methods used to ensure *continued* blinding *during implementation* include central allocation; sequentially numbered drug containers of identical appearance; sequentially numbered, opaque, sealed envelopes; *electronic medical record for "point-of-care" or "clinically integrated" randomized trials*; or equivalent methods.
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that the research personnel and subjects were adequately blinded to study group, and it is unlikely that they could have broken the blinding during the study, OR it is deemed that lack of adequate blinding during the study would not appreciably bias results.
Low	*Mark as low quality / probably high risk of bias if:* There is indirect evidence that it was possible for research personnel or subjects to infer the study group, OR there is insufficient information provided about blinding to study group during the study (record "NR" as basis for answer). Note: Inadequate methods include using an open random allocation schedule (*e.g.,* a list of random numbers), assignment envelopes used without appropriate safeguards (*e.g.,* if envelopes were unsealed or non-opaque or not sequentially numbered), alternation or rotation; date of

Data Quality Rating	Criteria **Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015)** **(Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font**
	birth; case record number; or any other explicitly unconcealed procedure. For example, if the use of assignment envelopes is described, but it remains unclear whether envelopes were sequentially numbered, opaque and sealed.
Critically deficient	*Mark as critically deficient / definitely high risk of bias if:* There is direct evidence for lack of adequate blinding of the study group including no blinding or incomplete blinding of research personnel and subjects. For some treatments, such as behavioral interventions, allocation to study groups cannot be concealed.
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*
Domain 3. Attrition	
Metric 3. Were outcome data complete without attrition or exclusion from analysis?	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that there was no loss of subjects during the study and outcome data were complete, OR loss of subjects (*i.e.,* incomplete outcome data) was adequately addressed and reasons were documented when human subjects were removed from a study or analyses. Review authors should be confident that the participants included in the analysis are exactly those who were randomized into the trial. Acceptable handling of subject attrition includes: very little missing outcome data (less than 10% in each group (Genaidy et al. 2007)); reasons for missing subjects unlikely to be related to outcome (for survival data, censoring unlikely to be introducing bias); missing outcome data balanced in numbers across study groups, with similar reasons for missing data across groups, OR analyses (such as intention-to-treat analysis) in which missing data have been imputed using *and applying the most* appropriate methods *and assumptions* (insuring that the characteristics of subjects lost to follow up or with unavailable records are described in identical way and are not significantly different from those of the study participants). Note: Participants randomized but subsequently found not to be eligible need not always be considered as having missing outcome data (Higgins and Green 2011).
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that loss of subjects (*i.e.,* incomplete outcome data) was adequately addressed and reasons were documented when human subjects were removed from a study, OR it is deemed that the proportion lost to follow-up would not appreciably bias results (less than 20% in each group (Genaidy et al. 2007)). This would include reports of no statistical differences in characteristics of subjects lost to follow up or with unavailable records from those 20 OHAT Risk of Bias Tool (January 2015) of the study participants. Generally, the higher the ratio of participants with missing data to participants with events, the greater potential there is for bias. For studies with a long duration of follow-up, some withdrawals for such reasons are inevitable.
Low	*Mark as low quality / Probably High risk of bias if:* There is indirect evidence that loss of subjects (*i.e.,* incomplete outcome data) was unacceptably large (greater than 20% in each group (Genaidy et al. 2007)) and not adequately addressed *(such as not addressed, or addressed using inadequate or*

Data Quality Rating	Criteria Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015) (Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font
	inappropriate imputation methods), OR there is insufficient information provided about numbers of subjects lost to follow-up (record "NR" as basis for answer).
Critically deficient	*Mark as critically deficient / Definitely high risk of bias if:* There is direct evidence that loss of subjects (*i.e.,* incomplete outcome data) was unacceptably large and not adequately addressed. Unacceptable handling of subject attrition includes: reason for missing outcome data likely to be related to true outcome, with either imbalance in numbers or reasons for missing data across study groups; or potentially inappropriate application of imputation.
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*
Domain 4. Exposure measurement bias	
Metric 4. Can we be confident in the exposure characterization?	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that the exposure (including purity and stability of the test substance and compliance with the treatment, if applicable) was independently characterized and purity confirmed generally as ≥99%~~3~~ for single substance or non-mixture evaluations (see NTP 2006 for example of study effects attributable to impurities of approximately 1%), AND that exposure was consistently *or appropriately* administered (*i.e.,* with the same method and time-frame) across treatment groups.
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that the exposure (including purity and stability of the test substance and compliance with the treatment, if applicable) was independently characterized and purity confirmed generally as ≥99%3 (*i.e.,* the supplier of the chemical provides documentation of the purity of the chemical), OR direct evidence that purity was independently confirmed as ≥98% it is deemed that impurities of up to 2% would not appreciably bias results, AND there is indirect evidence that exposure was consistently administered (*i.e.,* with the same method and time-frame) across treatment groups.
Low	*Mark as low quality / probably high risk of bias if:* There is indirect evidence that the exposure (including purity and stability of the test substance and compliance with the treatment, if applicable) was assessed using poorly validated methods, *OR there were substantial deviations from the intended protocol,* OR there is insufficient information provided about the validity of the exposure assessment method, but no evidence for concern (record "*insufficient information* ~~NR~~" as basis for answer).
Critically deficient	*Mark as critically deficient / definitely high risk of bias if:* There is direct evidence that the exposure (including purity and stability of the test substance and compliance with the treatment, if applicable) was assessed using poorly validated methods.
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric

Data Quality Rating	Criteria **Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015)** **(Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font**
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*
Domain 5. Outcome assessment	
Metric 5A. Can we be confident in the outcome assessment?	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that the outcome was assessed *consistently across study groups* using well-established methods (*e.g.,* the "gold standard" with validity and reliability >0.70 Genaidy et al. 2007), AND subjects had been followed for the same length of time in all study groups. Acceptable assessment methods will depend on the outcome, but examples of such methods may include: objectively measured with diagnostic methods, measured by trained interviewers, obtained from registries (Shamliyan et al. 2010), AND there is direct evidence that the outcome assessors (including study subjects, if outcomes were self-reported) were adequately blinded to the study group, and it is unlikely that they could have broken the blinding prior to reporting outcomes.
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that the outcome was assessed using acceptable methods (*i.e.,* deemed valid and reliable but not the gold standard) (*e.g.,* validity and reliability ≥0.40 Genaidy et al. 2007), AND subjects had been followed for the same length of time in all study groups [Acceptable, but not ideal assessment methods will depend on the outcome, but examples of such methods may include proxy reporting of outcomes and mining of data collected for other purposes], OR it is deemed that the outcome assessment methods used would not appreciably bias results, AND there is indirect evidence that the outcome assessors (including study subjects, if outcomes were self-reported) were adequately blinded to the study group, and it is unlikely that they could have broken the blinding prior to reporting outcomes, OR it is deemed that lack of adequate blinding of outcome assessors would not appreciably bias results, which is more likely to apply to objective outcome measures.
Low	*Mark as low quality / Probably High risk of bias if:* There is indirect evidence that the outcome assessment method is an insensitive instrument (*e.g.,* a questionnaire used to assess outcomes with no information on validation), OR the *outcome assessment method or* length of follow up differed by study group, OR there is indirect evidence that it was possible for outcome assessors (including study subjects if outcomes were self-reported) to infer the study group prior to reporting outcomes, OR there is insufficient information provided about blinding of outcome assessors (record "*not reported* ~~NR~~" *in the comment* ~~as basis for answer~~).
Critically deficient	*Mark as critically deficient / definitely high risk of bias if:* There is direct evidence that the outcome assessment method is an insensitive instrument, OR the length of follow up differed by study group, OR there is direct evidence for lack of adequate blinding of outcome assessors (including study subjects if outcomes were self-reported), including no blinding or incomplete blinding.
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance.*

Data Quality Rating	Criteria **Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015)** **(Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font**
Metric 5B. *Selective Reporting:* Were all measured outcomes reported?	
High	*Mark as high quality / definitely low risk of bias if:* There is direct evidence that all of the study's measured outcomes (primary and secondary) outlined in the protocol, methods, abstract, and/or introduction (that are relevant for the evaluation) have been reported. This would include outcomes reported with sufficient detail to be included in meta-analysis or fully tabulated during data extraction and analyses had been planned in advance.
Medium	*Mark as medium quality / probably low risk of bias if:* There is indirect evidence that all of the study's measured outcomes (primary and secondary) outlined in the protocol, methods, abstract, and/or introduction (that are relevant for the evaluation) have been reported, OR analyses that had not been planned in advance (*i.e.,* retrospective unplanned subgroup analyses) are clearly indicated as such and it is deemed that the unplanned analyses were appropriate and selective reporting would not appreciably bias results (*e.g.,* appropriate analyses of an unexpected effect). This would include outcomes reported with insufficient detail such as only reporting that results were statistically significant (or not).
Low	*Mark as low quality / Probably High risk of bias if:* There is indirect evidence that all of the study's measured outcomes (primary and secondary) outlined in the protocol, methods, abstract, and/or introduction (that are relevant for the evaluation) have been reported, OR and there is indirect evidence that unplanned analyses were included that may appreciably bias results, OR there is insufficient information provided about selective outcome reporting (record "*not reported* ~~NR~~" *in the comment* ~~as basis for answer~~).
Critically deficient	*Mark as critically deficient / Definitely high risk of bias if:* There is direct evidence that all of the study's measured outcomes (primary and secondary) outlined in the protocol, methods, abstract, and/or introduction (that are relevant for the evaluation) have not been reported. In addition to not reporting outcomes, this would include reporting outcomes based on composite score without individual outcome components or outcomes reported using measurements, analysis methods or subsets of the data (*e.g.,* subscales) that were not pre-specified or reporting outcomes not pre-specified, or that unplanned analyses were included that would appreciably bias results.
Not rated/Not Applicable	*Mark as N/A if:* - Do not select for this metric.
Reviewer's comments	*Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance*
Overall Quality Determination (OQD)	
Additional Comments	Additional comments:
Based on your professional judgement, would you upgrade or	*Select one of the following:* Yes, I would upgrade the paper Briefly describe why you decided to upgrade this study: Yes, I would downgrade the paper

Data Quality Rating	Criteria Note: These criteria are from the OHAT Risk of Bias Rating Tool for Human and Animal Studies (NTP, 2015) (Modifications Documented as: Additions in *Italics* and Deletions in ~~Strikethrough~~ Font
downgrade this study's OQD?	Briefly describe why you decided to downgrade this study: Neither – Keep quality rating as is
Specify which OQD you would give this paper (either confirm the auto calculated judgement OR suggest a new one based on your professional judgement?	High Medium Low Uninformative

5.5.2.2 Animal Toxicity Studies

As a result of feedback from NASEM, the SACC, and multiple external stakeholders, OPPT explored ways to harmonize its Systematic Review Protocol with the IRIS Systematic Review Handbook. Besides being responsive to feedback, this effort was envisioned to have several additional benefits. It would facilitate the sharing of systematic review outputs between programs. This would not only make reviews reusable by other Agency units, but also could mean that chemical-specific assessments could be split up into modules, with each Agency unit sharing their results to form a final assessment and, in turn, would conserve Agency resources. Harmonization of the protocols would also avoid waste of government funds (which is an imperative for all Agency managers) by not having employees and contractors in different EPA offices performing substantially similar reviews on the same references. Finally, it would prevent divergent conclusions from being reached by different parts of EPA within a very limited timeframe.

The process of harmonizing the TSCA Systematic Review Protocol with the IRIS Systematic Review Handbook was a collaborative effort between OPPT and ORD. The OPPT team developed an IRIS/TSCA crosswalk that mapped corresponding IRIS and TSCA data quality evaluation domains. The IRIS data quality evaluation tool has fewer metrics compared to the old TSCA tool – an IRIS domain consisting of one metric might have a corresponding domain on the old TSCA form that consisted of several metrics; hence, multiple old TSCA metrics were mapped into a smaller number of IRIS metrics (many-to-one). Systematic review practitioners in both offices reviewed the mapping and confirmed that the data quality considerations on the old TSCA form were captured in the IRIS form. Therefore, new harmonized TSCA forms were developed based on the mapping of IRIS metrics to TSCA domains. Once general agreement was reached, a small number of references were used for calibration of the new forms to ensure 1) that the results were concordant between OPPT and IRIS and 2) that the results were concordant between the old TSCA data quality evaluation form and the harmonized data quality evaluation form. Once both the systematic review project managers and the teams of practitioner/ evaluators were satisfied, the harmonized TSCA forms were finalized and put into use.
Data quality evaluation of human health animal toxicity studies was conducted using the new harmonized data quality evaluation form. The impetus for development of this form was described above, the goal of which was to harmonize the data evaluation form from the existing TSCA Systematic Review Protocol with that from the IRIS Systematic Review Handbook.

Table 5-7 describes the six domains and lists the number of metrics in each domain included in the new harmonized TSCA form. Because there are fewer domains in the IRIS Systematic Review Handbook than the TSCA Systematic Review Protocol, there was a many-to-one mapping from the old TSCA data quality evaluation form to the new harmonized TSCA data quality evaluation form as illustrated in the far-right column in Table 5-7. The far-right column depicts the individual metrics from the old TSCA data quality evaluation form that were mapped to the new harmonized TSCA data quality evaluation form. Moreover, Table 5-7 defines the domains in the new harmonized TSCA data quality evaluation form and describes how the old TSCA evaluation form metrics align with this new language. Detailed descriptions of each old TSCA form metrics in Table 5-7 can be found in Appendix Q of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021).

The new harmonized TSCA data quality evaluation form is described in Table 5-8 below. This form is applicable to the data quality evaluation of animal toxicity studies beyond HHCB and thus will also be used in the systematic review of studies reporting exposure to other TSCA high priority substances.

With the impetus of preserving historic context and educate evaluators, explanatory text summarizing the origin of the new harmonized forms and how the old TSCA metrics map to the new harmonized TSCA domains in data evaluation forms can be found in the header row of Table 5-8. Extensive calibration sessions were completed to ensure the team of contractors and EPA staff were trained and confident that the two forms (*i.e.,* old TSCA form and harmonized TSCA form) produced equivalent results. Finally, all metrics in the data quality evaluation form include a comment box for reviewers to catalogue reference details not otherwise captured in the metric text, reading: "Reviewer comments: Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance."

Table 5-7. Summary of Harmonized TSCA Domains and Domain Definitions, Harmonized TSCA Form Metrics, and Old TSCA From Metrics for Human Health Animal Toxicity Studies

Harmonized TSCA Form Domains	Harmonized TSCA Form Domain Definition	Harmonized TSCA Form Metrics	Old TSCA Form Metrics
Domain 1. Reporting quality	Domain 1 evaluates the reporting of details in the study. It uses two main categories of information: (1) critical, and (2) important. Critical information is considered essential and without it, the quality of the study may not be sufficiently evaluated. Important information is not required for evaluation, but it supports the critical information.	Single metric	Metrics 13, 14, and 15
Domain 2. Selection and performance	Domain 2 evaluates the risk of bias using metrics that assess allocation methods and observational bias. The randomization of the study design ensures that the effect observed is due to the exposure. Bias in observational measurements may lead to questions about the validity and reliability about the results of an experiment.	Metrics 2.1 and 2.2	Metrics 6 and 19

Harmonized TSCA Form Domains	Harmonized TSCA Form Domain Definition	Harmonized TSCA Form Metrics	Old TSCA Form Metrics
Domain 3. Confounding/Variable Control	Domain 3 evaluates the use of appropriate controls and/or comparators to discern the relationship between exposure to the test substance and the outcome(s)/endpoint(s) of interest. The use of controls and comparator and accounting for confounding variables minimizes bias so that the effect can be specifically attributed to the exposure.	Single metric	Metrics 4 and 5, 20, and 21
Domain 4. Selective Reporting and Attrition	Domain 4 evaluates the risk of bias due to selective reporting and attrition. The study should report intended sample sizes for all outcome(s)/endpoint(s) of interest, and discrepancies between the number of animals used to generate data points should also be adequately addressed. Attrition of animals during the experiment should be explained and transparent.	Single metric	Metric 22
Domain 5. Exposure methods sensitivity	Domain 5 evaluates the chemical administration and characterization. The information reported on the test substance should verify that exposure is in fact to the substance of interest, and the route and method of administration should be appropriate for the measured outcome(s)/endpoint(s) of interest. The timing, frequency, and duration of exposure should be suitable for all outcome(s)/endpoint(s) of interest.	Metrics 5.1 and 5.2	Metrics 1, 2, 3, 7, 8, 9, 10, and 12
Domain 6. Outcome measures and results display	Domain 6 evaluates the sensitivity of the experiments that are used to characterize or measure the specific endpoint(s)/outcome(s) of interest. The methods used should reliably and reproducibly detect a response due to exposure for the specific endpoint(s)/outcome(s) of interest. The analysis and presentation of the results should be interpretable and transparent for the specific endpoint(s)/outcome(s) of interest.	Metrics 6.1 and 6.2	Metrics 11, 16, 17, 18, 23, and 24

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Table 5-8. Harmonized TSCA Data Quality Evaluation from for Human Health Animal Toxicity Studies

Data Quality Rating	Description
Domain 1. Reporting quality (Combines Old TSCA Form Metrics 13, 14, and 15 from the Test Animals Domain)	
Does the study report information for evaluating the design and conduct of the study for the endpoint(s)/outcome(s) of interest? This Domain uses two main categories of information: (1) critical, and (2) important. Critical information necessary to perform study evaluation: Test animals' species, test article identity (*i.e.,* CASRN, chemical name, and/or structure), dose/concentration levels and duration of exposure, route (*e.g.,* oral; inhalation), qualitative or quantitative results for at least one endpoint of interest. Important information for evaluating the study methods: Test animal characteristics: source (*e.g.,* commercial source or laboratory-maintained colony), strain, age and/or life stage, sex, starting body weight, and/or parity (whether the test animals have been previously pregnant). For example, reporting animals to be 'mature' prior to starting the study leaves uncertainty and potential impact to results and may not be considered high quality. General animal husbandry conditions and procedures: temperature, humidity, light/dark cycle, diet, water availability, number of animals per cage throughout the study Exposure methods: test substance source, purity (or grade), method of administration Experimental design: frequency of exposure (*e.g.,* hours/day, days/week), number of animals per study group, animal age and life stage during exposure and at endpoint/outcome evaluation, as Applicable to the study purpose/objective Endpoint evaluation methods: assays or procedures used to measure the endpoints/outcomes of interest. The presence or absence of all critical information determines whether a ranking is acceptable, or not. If/when critical information is missing, this Domain receives an uninformative ranking. The confidence level of acceptable, *e.g.,* high, medium, or low, corresponds to the amount of important information provided, in addition to the critical information. The confidence ranking for acceptable information should be justified and the assessor should identify which important information was provided in the study to support the assigned ranking. Note: This domain is limited to reporting. Other aspects (*i.e.,* appropriateness) of the exposure methods, experimental design, and endpoint evaluation methods are evaluated using the domains related to risk of bias and study sensitivity. The considerations below typically do not need to be refined by assessment teams, although in some instances the important information may be refined depending on the endpoints/outcomes of interest or the chemical under investigation. As for any study quality domain/metric, assessor judgment and rationale for ranking this domain should be given for the study and in the form of comments. Typically, a ranking given for this domain will not change across endpoints/outcomes investigated by the study. In the rationale, reviewers should indicate whether the study adhered to GLP, OECD, or other testing guidelines.	
High	*Mark as high/good if*: All critical and important information is reported or for the endpoints/outcomes of interest. The information could also be inferred from a reference document (*e.g.,* cited paper, manufacturer's website, guideline).
Medium	*Mark as medium/adequate if*: All critical information is reported but some combination important information is missing. However, the missing information is not expected to significantly impact the study evaluation.

Data Quality Rating	Description
Low	*Mark as low/deficient if*: All critical information is reported but important information is missing that is expected to significantly reduce the ability to evaluate the study.
Critically Deficient	*Mark as critically deficient if*: Study report is missing any pieces of critical information.
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 2. Selection and performance (Corresponds to Old TSCA Form Metrics 6 and 9)	
Metric 2.1. Allocation Were animals assigned to experimental groups using a method that minimizes selection bias? The considerations below typically do not need to be refined by assessment teams. A judgment and rationale for this domain should be given for each cohort or experiment in the study. Did each animal or litter have an equal/random chance of being assigned to any experimental group (*i.e.,* random allocation)? Is the allocation method described? Aside from randomization, were any steps taken to balance variables and/or pre-study test animal characteristics or other modifying factors across experimental groups during allocation? What is the expected and extent of the impact on study results if there is failure to randomize and/or normalize animal allocation? Is it significant or negligible?	
High	*Mark as high/good if*: Experimental groups were randomized, and any specific randomization procedure was described or inferable from a reference document (*e.g.,* cited paper, manufacturer's website, guideline). (*e.g.,* computer-generated scheme). Normalization of body weight to make sure average body weight is similar across doses if combined with a randomization scheme can be rated as *High*.
Medium	*Mark as medium/adequate if*: Authors report that groups were randomized but do not describe the specific procedure used (*e.g.,* "animals were randomized"). Alternatively, authors used a nonrandom method to control for important modifying factors across experimental groups (*e.g.,* body-weight normalization without use of randomization).
Low	*Mark as low/deficient if*: No indication of randomization of groups or other methods (*e.g.,* normalization) to control for important modifying factors across experimental groups.
Critically Deficient	*Mark as critically deficient if*: Bias in the animal allocations was explicitly reported or inferable from a reference document.

Data Quality Rating	Description
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2.2. Observational bias/blinding Did the study implement measures to reduce observational bias? The considerations below typically do not need to be refined by the assessment teams. It is recommended that project assessors collectively build consensus to identify highly subjective measures of endpoints/outcomes where observational bias may strongly influence results prior to performing evaluations. A judgment and rationale for this domain should be given for each endpoint/outcome or group of endpoints/outcomes investigated in the study. Does the study report blinding or other methods/procedures for reducing observational bias? This can apply to endpoints/outcomes that require heavy research practitioner handling or awareness of treatment/exposure groups during outcome assessment that may significantly impact study results. If not, did the study describe a design or approach for quality control of observational bias, for which such procedures can be inferred from a reference cited in the document? What is the expected and extent of the impact on study results of failure to implement (or report implementation) of these methods/procedures? Is it significant or negligible?	
High	*Mark as high/good if*: Measures to reduce observational bias were described (*e.g.,* blinding to conceal treatment groups during endpoint evaluation; consensus-based evaluations of histopathology-lesions).
Medium	*Mark as medium/adequate if*: Methods for reducing observational bias (*e.g.,* blinding) can be inferred from a cited reference (*e.g.,* cited paper or guideline) or were reported but were described incompletely. OR Measures to reduce observational bias were not described AND the potential concern for bias was mitigated because the outcomes were not subjective and/or based on use of automated/computer-driven systems, standard laboratory kits, simple objective measures (*e.g.,* body or tissue weight), or screening-level evaluations of histopathology.
Low	*Mark as low/deficient if*: Measures to reduce observational bias were not described AND the potential impact on the results is significant (*e.g.,* outcome measures are subjective).
Critically Deficient	*Mark as critically deficient if*: Strong evidence for observational bias that impacted the results.
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.

Data Quality Rating	Description
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Confounding/variable control (Combines TSCA Metrics 4 and 5 from the Test Design Domain, Metric 20, and Metric 21 from the Confounding/Variable Control Domain)	
Are variables with the potential to confound or modify results controlled for and consistent across all experimental groups? The considerations below may need to be refined by assessment teams, as the specific variables of concern can vary by experiment or chemical. A judgment and rationale for this domain should be given for each cohort or experiment in the study, noting when the potential for confounding is restricted to specific endpoints/outcomes. Are there differences across the study groups (*e.g.,* co-exposures, vehicle, diet, palatability, husbandry) that could bias the results or introduce an unaccounted for or confounding variable? What is the expected extent of the impact on study results if confounding variables are identified? Is it significant or negligible?	
High	*Mark as high/good if*: Outside of the exposure of interest, variables that are likely to confound or modify results appear to be controlled for and consistent across experimental groups.
Medium	*Mark as medium/adequate if*: Some concern that variables that were likely to confound or modify results were uncontrolled or inconsistent across groups but are expected to have a minimal impact on the results.
Low	*Mark as low/deficient if*: Notable concern that potentially confounding variables were uncontrolled or inconsistent across groups and are expected to substantially impact the results.
Critically Deficient	*Mark as critically deficient if*: One or more confounding variables is known or presumed to be uncontrolled or inconsistent across groups and is expected to be a primary driver of the results and/or to distort the relationship between the exposure and outcome(s) of interest.
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Selective reporting and attrition (Combines TSCA Metric 22 from the Confounding/Variable Control Domain)	
Did the study report results for all prespecified outcomes and tested animals? Note: This domain does not consider the appropriateness of the analysis/results presentation. This aspect of study quality is evaluated in another domain.	

Data Quality Rating	Description
The considerations below typically do not need to be refined by assessment teams. A judgment and rationale for this domain should be given for each cohort or experiment in the study. Selective reporting bias: Are all results presented for endpoints/outcomes described in the methods? Attrition bias: Are all animals accounted for in the results? If there are discrepancies, do the authors provide an explanation (*e.g.,* death or unscheduled sacrifice during the study)? If unexplained results omissions and/or attrition are identified, what is the expected impact on the interpretation of the results?	
High	*Mark as high/good if*: Quantitative or qualitative results were reported for all prespecified outcomes (explicitly stated or inferred from a cited reference, such as a guideline or methodology peer-reviewed paper), exposure groups and evaluation time points. Data not reported in the primary article are available from supplemental material. If results omissions or animal attrition are identified, the authors provide an explanation, and these are not expected to impact the interpretation of the results.
Medium	*Mark as medium/adequate if*: Quantitative or qualitative results were reported for most prespecified outcomes (explicitly stated or inferred from a cited reference, such as a guideline or methodology peer-reviewed paper), exposure groups and evaluation time points. Omissions and/or attrition are not explained but are not expected to significantly impact the interpretation of the results.
Low	*Mark as low/deficient if*: Quantitative or qualitative results are missing for two or more prespecified endpoints (explicitly stated or inferred from a cited reference, such as a guideline or peer-reviewed methodology paper), exposure groups, and evaluation time points and/or there is high animal attrition; omissions and/or attrition are not explained and may significantly impact the interpretation of the results.
Critically Deficient	*Mark as critically deficient if*: Extensive results omission and/or animal attrition are identified and prevents comparisons of results across treatment groups.
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 5. Exposure methods sensitivity (Combines TSCA Metrics from the Test Substance and Exposure Characterization Domains [Metrics 1, 2, 3, ,7 ,8, 9, 10, and 12])	

Data Quality Rating	Description
Metric 5.1. Chemical administration and characterization Did the study adequately characterize exposure to the chemical of interest and the exposure administration methods? Was the route and method of exposure appropriate? Note: Relevance and utility of the routes of exposure are considered in the PECO criteria for study inclusion and during evidence synthesis. It is essential that the considerations below are considered, and potentially refined, by assessment teams, as the specific variables of concern can vary by chemical (*e.g.,* stability may be an issue for one chemical but not another). A judgment and rationale for this domain should be given for each cohort or experiment in the study. Are there concerns [specific to this chemical] regarding the source and purity and/or composition (*e.g.,* identity and percent distribution of different isomers) of the chemical? If so, can the purity and/or composition be obtained from the supplier (*e.g.,* as reported on the website)? Was independent analytical verification of the test article purity and composition performed? Did the authors take steps to ensure the reported exposure levels were accurate (*e.g.,* reporting by the authors of calculated doses in feeding/drinking water studies or sufficient information to independently calculate doses from concentrations in feed or water)? Are there concerns about the methods used to administer the chemical (*e.g.,* inhalation chamber type, gavage volume) or methods of test substance preparation or storage? For inhalation studies: Were target concentrations confirmed using reliable analytical measurements in chamber air? For oral studies: If necessary, based on consideration of chemical specific-knowledge (*e.g.,* instability in solution; volatility) and/or exposure design (*e.g.,* the frequency and duration of exposure), were chemical concentrations in the dosing solutions or diet/drinking water analytically confirmed? ** *If methods were cited to another publication, review the relevant methods in the original publication and consider this information as you rank this metric. Methods papers will be linked in HERO to the publication being evaluated.*	
High	*Mark as high/good if*: Chemical administration and characterization are complete (*i.e.,* test substance source and purity are appropriate, and analytic verification of the test article are provided). There are no concerns about the composition, stability, or purity of the administered chemical, or the specific methods of administration. For inhalation studies, chemical concentrations in the exposure chambers are verified using reliable analytical methods.
Medium	*Mark as medium/adequate if*: Some uncertainties in the chemical administration and characterization are identified but these are expected to have minimal impact on interpretation of the results (*e.g.,* source and vendor-reported purity are presented, but not independently verified; purity of the test article is suboptimal but not concerning; for inhalation studies with gases, actual exposure concentrations are missing or verified with less reliable methods; for oral and dermal studies, there are minor uncertainties about precision of dose levels or exposure concentrations).
Low	*Mark as low/deficient if*: Uncertainties in the exposure characterization are identified and are expected to substantially impact the results (*e.g.,* source of the test article was not reported; levels of impurities are substantial or concerning; deficient administration methods, such as use of static inhalation chambers or a gavage volume considered too large for the species and/or lifestage at exposure; for inhalation studies with aerosols or vapors,

Data Quality Rating	Description
	actual exposure concentrations are missing or verified with less reliable methods; for oral and dermal studies, there is substantial ambiguity about precision of dose levels or exposure concentrations).
Critically Deficient	*Mark as critically deficient if*: Uncertainties in the exposure characterization are identified and there is reasonable certainty that the results are largely attributable to factors other than exposure to the chemical of interest (*e.g.,* identified impurities are expected to be a primary driver of the results).
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 5.2. Exposure timing, frequency, and duration Was the timing, frequency, and duration of exposure sensitive for the endpoint(s)/outcome(s) of interest? Considerations for this domain are highly variable depending on the endpoint(s)/outcome(s) of interest and must be refined by assessment teams. A judgment and rationale for this domain should be given for each endpoint/outcome or group of endpoints/outcomes investigated in the study. Does the exposure period include the critical window of sensitivity (*e.g.,* to detect developmental effects of interest)? Was the duration and frequency of exposure sensitive for detecting the endpoint of interest?	
High	*Mark as high/good if*: The timing, duration, and frequency of the exposure was sensitive, and the exposure included the critical window of sensitivity (if known).
Medium	*Mark as medium/adequate if*: The duration and frequency of the exposure was sensitive, and the exposure covered most of the critical window of sensitivity (if known).
Low	*Mark as low/deficient if*: The timing, duration, and frequency of the exposure is not sensitive or did not include most of the critical window of sensitivity (if known). These limitations are expected to bias the results towards the null.
Critically Deficient	*Mark as critically deficient if*: The exposure design is inappropriate for evaluating the outcome(s) of interest and is expected to strongly bias the results towards the null. The rationale should indicate the specific concern(s).
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Domain 6. Outcome measures and results display (Combines TSCA Metrics from the Outcome Assessment and Data Presentation and Analysis Domains, and Metric 23 from the Data Presentation and Analysis Domain) [Metrics 11, 16, 17, 18, 23, and 24])	
Metric 6.1. Are the procedures sensitive and specific for evaluating the endpoint(s)/outcome(s) of interest? Considerations for this domain are highly variable depending on the endpoint(s)/outcome(s) of interest and must be refined by assessment teams. A judgment and rationale for this domain should be given for each endpoint/outcome or group of endpoints/outcomes investigated in the study. Are there concerns regarding the sensitivity, specificity, and/or validity of the protocols? Is the species appropriate? Are there serious concerns regarding the sample size? Are there concerns regarding the timing of the endpoint assessment? Examples of potential concerns include: Selection of protocols that are insensitive or nonspecific for the endpoint of interest Evaluations did not include all treatment groups (*e.g.,* only control and high dose) Use of unreliable methods to assess the outcome Assessment of endpoints at inappropriate or insensitive ages, or without addressing known endpoint variation (*e.g.,* due to circadian rhythms, estrous cyclicity) The study was conducted appropriately in relation to the evaluation domain, and any deficiencies, if present, are minor and would not be expected to influence the study results Decreased specificity or sensitivity of the response due to the timing of endpoint evaluation, as compared to exposure (*e.g.,* short acting depressant or irritant effects of chemicals; insensitivity due to prolonged period of non-exposure prior to testing) **** If methods were cited to another publication, review the relevant methods in the original publication and consider this information as you rank this metric. Methods papers will be linked in HERO to the publication being evaluated.*	
High	*Mark as high/good if*: The study was conducted appropriately in relation to the evaluation domain, and any deficiencies, if present, are minor and would not be expected to influence the study results.
Medium	*Mark as medium/adequate if*: There are methodological limitations relating to the evaluation domain, but that those limitations are not likely to be severe or have a notable impact on the results.
Low	*Mark as low/deficient if*: Biases or deficiencies were identified that are interpreted as likely to have had a notable impact on the results or that may prevent reliable interpretation of the study findings.
Critically Deficient	*Mark as critically deficient if*: The conduct of the study introduced a serious flaw that makes the observed effect(s) uninterpretable. Note: Sample size alone is not a reason to conclude an individual study is critically deficient.
Not Rated/Not Applicable	*Mark as N/A if*:

Data Quality Rating	Description
	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 6.2. Results presentation Are the results presented in a way that makes the data usable and transparent? Considerations for this domain are highly variable depending on the outcomes of interest and must be refined by assessment teams. A judgment and rationale for this domain should be given for each endpoint/outcome or group of endpoints/outcomes investigated in the study. Does the level of detail allow for an informed interpretation of the results? Are the data analyzed, compared, or presented in a way that is inappropriate or misleading? Examples of potential concerns include: Nonpreferred presentation (*e.g.,* developmental toxicity data averaged across pups in a treatment group, when litter responses are more appropriate; presentation of absolute organ-weight data when relative weights are more appropriate) Failing to present quantitative results either in tables or figures Lack of full presentation of the data (*e.g.,* presentation of mean without variance data; concurrent control data are not presented)	
High	*Mark as high/good if*: There was a full quantitative presentation of results (*e.g.,* means and SE or SD for continuous data; incidence data for categorical data; or individual animal results were presented). Any omissions are minor and are not expected to impact the interpretation of the results.
Medium	*Mark as medium/adequate if*: Some details of the results are missing, but the missing information is not expected to have a notable impact on the interpretation of the results.
Low	*Mark as low/deficient if*: Data were analyzed, compared, or presented in a way that is inappropriate or misleading (*e.g.,* the authors report a treatment-related effect on a quantitative endpoint, but only qualitative results are provided).
Critically Deficient	*Mark as critically deficient if*: Deficiencies in results presentation make the observed effect(s) uninterpretable.
Not Rated/Not Applicable	*Mark as N/A if*: Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Overall Quality Determination (OQD)	
Additional Comments	Additional Comments:

Data Quality Rating	Description
Based on your professional judgement, would you upgrade or downgrade this study's OQD?	*Select one of the following:* Yes, I would upgrade the paper Briefly describe why you decided to upgrade this study: Yes, I would downgrade the paper Briefly describe why you decided to downgrade this study: Neither – Keep quality rating as is
Specify which OQD you would give this paper (either confirm the auto calculated judgement OR suggest a new one based on your professional judgement?	High Medium Low Uninformative

5.6 Dermal Absorption

EPA's general approach to data evaluation and extraction of relevant data sources under TSCA is described in Sections 5 and 6, respectively of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). For each study, one reviewer conducts the initial review, and a second reviewer provides the QC review. EPA uses DistillerSR to evaluate and extract dermal absorption studies; the information from DistillerSR is then coded for output into tables that accompany the published risk evaluations. EPA evaluated and extracted dermal absorption studies that met the PECO screening criteria described above in Section 4.7.

Animal *in vivo* dermal absorption studies were evaluated using an extensively modified version of the animal toxicity data quality metrics shown in Appendix Q.4.2 of U.S. EPA (2021). To evaluate *in vitro/ex vivo* dermal absorption studies, EPA developed data evaluation metrics from the metrics used to evaluate *in vitro* mechanistic studies and presented a draft version of these metrics in Appendix S of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). The sections below identify updates to these *in vivo* and *in vitro/ex vivo* criteria made since publication of the 2021 Draft Systematic Review Protocol.

Data extraction involves cataloguing experimental methods and results from the evaluated references. For *in vivo* studies, EPA extracts data on the matrices measured (*e.g.,* urine, carcass, exhaled air) and other information. For *in vitro* studies, EPA extracts information on the type of skin used (*e.g.,* source and area of body, thickness), the diffusion cell exposure set up (flow-through or static), and other data. For both *in vivo* and *in vitro/ex vivo* studies, EPA identifies the species used, whether skin was occluded, and information on the test substance and vehicle. As relevant, EPA extracts K_p/flux as well as fraction absorption information.

If adequate data are available from *in vivo* or *in vitro/ex vivo* (excised skin) studies, EPA will not evaluate, extract, or quantitively use data from the 3D human skin studies in risk evaluations. Currently, the 3D human skin equivalent models are not recommended by OECD Guidance (OECD Series on Testing and Assessment No. 156 [September 2022]) (OECD, 2022) for use in evaluating risks.

However, EPA may discuss the 3D models when integrating evidence and may consider evaluating them if no other experimental dermal absorption information is available.

For HHCB, EPA evaluated one *in vivo* study in rats and human subjects and two *in vitro* studies (one using human skin and one using porcine back skin) identified from the literature searching and filtering of dermal absorption data. EPA assigned a medium OQD to the rat component of the one *in vivo* study and a low OQD for the *in vitro* study using porcine back skin. For the *in vitro* study using human skin and the human subjects component of the *in vivo* study, EPA used DERs to evaluate study quality. EPA assigned a rating of acceptable/non-guideline to both studies.

The *Draft Data Quality Evaluation and Data Extraction Information for Dermal Absorption for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026c) provides details of the data extracted and evaluated, including metric rankings and the OQDs for evaluated data sources. The DERs used to evaluate the *in vitro* human skin study and the human subjects component of the *in vivo* study can be found in *Draft Data Evaluation Records for Human Health Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026a)

5.6.1 Data Quality Metrics – Animal *In Vivo*

Animal *in vivo* dermal absorption studies were evaluated using an extensively modified version of the animal toxicity data quality metrics shown in Appendix Q.4.2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). The domains are identical except Domain 4 now refers to test models (instead of test *animals*). EPA used OECD guidelines to develop the criteria for the evaluation of *in vivo* dermal absorption references (OECD, 2022, 2011, 2004a, b). Specifically, metrics were modified to address the standards used (metric 5), consistency of in exposure administration (metric 7), reporting of concentrations used (metric 8), exposure duration (metric 9), exposure groups and concentration (metric 10), characteristics of test animals and number of animal per group based on OECD 427 (metrics 11 and 13), outcome assessment methodology based on guidelines (metric 14), evaluation per group (metric 16), confounding variables (metric 17 and 18), data analysis, interpretation, and reporting (metric 19, 20, and 21). The full set of data quality metrics for *in vivo* animal studies are shown in Table 5-9.

Table 5-9. Data Quality Criteria for *In Vivo* Animal Dermal Absorption Studies

Data Quality Rating	Description
Domain 1. Test substance	
Metric 1. Test substance identity Was the test substance identified definitively (*i.e.,* established nomenclature, CASRN, physical nature, physical and chemical properties, and/or structure reported, including information on the specific form tested [*e.g.,* salt or base, valence state, isomer, if Applicable] for materials that may vary in form)? If test substance was a mixture, were mixture components and ratios characterized?	
High	The test substance (*i.e.,* chemical of interest) was identified definitively (*i.e.,* nomenclature, CASRN, structure) and where Applicable the specific form (*e.g.,* particle characteristics for solid state materials, salt or base, valence state, hydration state, isomer, radiolabel, etc.) was definitively and completely characterized. For mixtures, the components and ratios were characterized (*i.e.,* provided as concentration, ratio of percentage of the mixture or product). Additionally, for radiolabeled substances, the location of the radiolabel within the substance should be indicated, ideally with the radiolabel in a metabolically stable position

Data Quality Rating	Description
Medium	The test substance (*i.e.,* chemical of interest) was identified and the specific form was characterized (where Applicable). For mixtures, some components and components and ratios were identified and characterized but at least the chemical of interest has a percentage/concentration reported. There were minor uncertainties (*e.g.,* minor characterization details were omitted such as about the radiolabel) that were unlikely to have a substantial impact on results
Low	The test substance and form (if Applicable) were identified and the components and ratios of mixtures were characterized, but there were uncertainties regarding test substance identification or characterization that are likely to have a substantial impact on the results (*e.g.,* no information on isomer (or enantiomer) composition of differences could affect toxicokinetic properties, limited particle size information, omitted details regarding branched or straight chain structure).
Critically Deficient	The test substance identity and form (the latter if Applicable) could not be determined from the information provided (*e.g.,* nomenclature was unclear and CASRN or structure were not reported) **OR** For mixtures, the components and ratios were not characterized.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2. Test substance source Was the source of the test substance reported, including manufacturer and batch/lot number for materials that may vary in composition? If synthesized or extracted, was test substance identity verified by analytical methods?	
High	The source of the test substance was reported as a manufacturer or the production process was specifically identified. The batch/lot number was identified (for materials that may vary in composition), and the chemical identity was either certified by the source in the publication or could be verified on a manufacturer's website. **OR** The test substance identity was analytically verified by the laboratory that performed the toxicity study.
Low	The test substance was synthesized or extracted by a source other than the manufacturer [and no production process was identified]. **OR** The source was not reported. **AND** The test substance identity was NOT analytically verified by the performing laboratory.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 3. Test substance purity Was the purity or grade (*i.e.,* analytical, technical) of the test substance (including the radiolabeled substance) reported and adequate? Were impurities identified? Were impurities present in quantities that could influence the results? ~~Note that formaldehyde and other chemicals may require additional guidance that may differ from the guidance below.~~	

Data Quality Rating	Description
High	For discrete substances, the test substance purity **(including radiolabel)** and composition were such that any observed effects were highly likely to be due to the nominal test substance itself (*e.g.,* highly pure at >98% or analytical grade test substance or a formulation of lower purity that contains ingredients considered to be inert, such as water). ~~The radiopurity ideally should be greater than 95% and reasonable effort should be made to identify impurities present at or above 2%.~~ **AND** All components, including impurities and residual chemicals, were identified and the chemical of interest was the main component **(including the radiolabeled portion).**
Medium	The nature and quantity of reported impurities are such that study results were not likely to be substantially impacted by the impurities (impurities not known to induce outcome of interest at low levels, impurities are inert or GRAS, etc.). Regardless of the nature and purity, for discrete chemicals, the purity of the chemical of interest should be >70%, unless water is the only impurity.
Low	Purity and/or grade of test substance were not reported **(for both the labeled and unlabeled chemical).**
Critically Deficient	The nature and quantity of reported impurities (**for unlabeled and labeled substances)** were such that study results were likely to be due to one or more of the impurities. **AND/OR** For discrete chemicals, purity was <70% **(for unlabeled and labeled substances)** with an impurity other than water.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 2. Test design	
Metric 4. Randomized allocation of animals Did the study explicitly report randomized allocation of animals to study groups?	
Medium	The study reported that animals were randomly allocated into study groups **OR** Allocation was performed with an unbiased method with a non-random component to ensure similar baseline characteristics across groups (*e.g.,* methods that account for body weight to ensure appropriate distribution across groups)
Low	The study did not report how animals were allocated to study groups, or there were deficiencies regarding the allocation method that are likely to have a substantial impact on results (*e.g.,* allocation by animal number).
Critically Deficient	The study reported using a biased method to allocate animals to study groups (*e.g.,* judgement of investigator). This is a serious flaw that makes the study unusable.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 5. Standards for tests	

Data Quality Rating	Description
For assays with established criteria, were the test validity, acceptability, reliability, and/or QC criteria reported and consistent with current standards and guidelines? Were sufficient data provided to determine that the standards/guidelines have been met? **See Guidance for Reviewers to view examples of various criteria.** Example criteria: *Percent recovery:* 100±10% of the radioactivity as stated in OECD TG 427; 100±20% for volatile and unlabeled compounds as stated in OECD GD 28. *Coefficient of Variation*: **OECD 156 states that if the coefficient of variation is greater than 25%, then apply an adjustment.** ~~Variance across replicates should be measured and indicated when standard deviation exceeds 25%.~~	
Medium	Criteria used to determine the validity acceptability, reliability, and/or quality of the experiment (*e.g.,* percent recovery considered acceptable) were reported and consistent with current standards and guidelines, as/if Applicable and authors stated that results met those criteria, or the results provided enough detail to compare with the criteria.
Low	Few or no QC criteria were reported, however, the reported results provided enough information to evaluate how the study compared against the criteria stated in the study and/or external criteria and standards.
Critically Deficient	Inadequate information was provided on the standards used to evaluate the study results **AND** 1) the authors did not report whether the test met pre-established criteria, **OR** 2) inadequate data on results were presented to demonstrate the validity, acceptability, and reliability of the test when compared with current standards and guidelines or the pre-established standards/criteria identified by the authors. In this case, adequate QC cannot be performed.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Exposure characterization	
Metric 6. Preparation and storage of test substance (chemical) Did the study characterize preparation of the test substance and storage conditions? Were the frequency of preparation and/or storage conditions appropriate to the test substance stability and solubility (if Applicable)?	
High	The test substance preparation and/or storage conditions (*e.g.,* test substance stability, homogeneity, mixing temperature, stock concentration, stirring methods, storage conditions) were reported and appropriate for the test substance and application scenario (*e.g.,* stability and solubility in diluents or solvents confirmed especially if they differ from what is used commercially; volatile test substances prepared and stored in sealed containers; same stock solution for all exposure concentrations).
Medium	The test substance preparation and storage conditions were reported, but minor limitations in the test substance preparation and/or storage conditions were identified (*e.g.,* test substance formulations were stirred instead of centrifuged for a specific number of rotations per minute). **OR** There is an omission of details that are unlikely to have a substantial impact on results (*e.g.,*

Data Quality Rating	Description
	preparation/administration of test substance is described, but storage of stock solution is not reported; however, storage is unlikely to affect results based on likely stability over the time frame of the test or the physical and chemical properties of the chemical make concerns about volatility or solubility unlikely).
	Deficiencies in reporting of test substance preparation, and/or storage conditions are likely to have a substantial impact on results (*e.g.,* available information on physical and chemical properties suggests that stability and/or solubility of test substance in diluent/solvent may be poor). **OR** Information on preparation and storage was *not* reported and lack of details could substantially impact results (*e.g.,* preparation for volatile or low-solubility chemicals).
Critically Deficient	Serious flaws reported regarding test substance preparation and/or storage conditions will have critical impacts on dose/concentration estimates and make the study unusable (*e.g.,* instability of test substance, test substance volatilized rapidly from storage containers).
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 7. Consistency of exposure administration Were exposures administered consistently across study groups (*e.g.,* consistent volumes/area of skin surface used for application that are ≈5–10% of animal body surface (*e.g.,* 10 cm^2 for the rat), same area/location of body used for application)?	
High	Details of exposure administration were reported and exposures were administered consistently across study groups in a scientifically sound manner (*e.g.,* consistent volume and area of skin surface used for application, same area of body used for application for each animal and dose group).
Medium	Details of exposure administration were reported, but minor limitations in administration of exposures (*e.g.,* slight variations in surface area) were identified that are unlikely to have a substantial impact on results. **OR** Details of exposure administration are incompletely reported, but the missing information is unlikely to have a substantial impact on results.
Low	Details of exposure administration were reported, but deficiencies in administration of exposures (*e.g.,* moderate differences in of skin surface area used for application) that were reported or inferred from the text are likely to have a substantial impact on results. **OR** Details of exposure administration are insufficiently reported and the missing information is likely to have a substantial impact on results
Critically Deficient	Exposures were not administered consistently across and/or within study groups (*e.g.,* large differences in volume and area of skin surface used for application) resulting in serious flaws that make the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Metric 8. Reporting of concentrations Were exposure doses/concentrations or amounts of test substance applied to the skin reported without ambiguity (*e.g.,* point estimate instead of range, analytical instead of nominal, weight by weight vs. volume by volume)? Note: Ambiguity also applies to doses/concentrations if values were only reported as points on a figure without numerical values.	
High	The exposure doses/concentrations or amounts of test substance were reported without ambiguity (*e.g.,* point estimate instead of range, analytical/measured instead of nominal, weight vs. volume).
Medium	The exposure doses/concentrations or amounts of test substance were reported with some ambiguity (*e.g.,* range instead of point estimate OR nominal instead of analytical/measured, unclear if weight or volume-based).
Low	The exposure doses/concentrations or amounts of test substance were reported but with substantial ambiguity about precision (*e.g.,* only an estimated range AND only nominal instead of analytical measurements).
Critically Deficient	The exposure doses/concentrations or amounts of test substance were not reported, resulting in serious flaws that make the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 9. Exposure duration Was the exposure duration (*e.g.,* hours) reported and was it appropriate for this study type and/or outcome(s) of interest? Was the duration of exposure relevant to conditions of use and physical-chemical properties of the test substance? Did measurements continue post-exposure to account for retained dose in skin?	
High	The exposure duration (*e.g.,* hours) was reported and was appropriate based on the expected human exposure duration (typically at least 6 hours up to 24 hours following chemical application; if experiment continues beyond 1 day, measurements should continue daily in order to evaluate all excreta and tissues). A shorter exposure duration may also be included but is less useful unless the substance is volatile, the results demonstrate that absorption approached completion (*e.g.,* nothing left in the skin wash or tape strip samples), or the timepoint is used only for K_p/flux measurements.
Low	The duration(s) of exposure differed from current standards and guidelines for studies of this type (typically <6–24 hours prior to washing with excreta and/or measurements not continued without justification), and the differences may have a substantial impact on results.
Critically Deficient	No information on exposure duration(s) was reported **OR** the exposure duration was not appropriate **OR** Duration(s) differed significantly from studies of the same or similar types and these differences (most likely shorter duration) are likely to have a substantial impact on interpretation of results.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Metric 10. Number of exposure groups and concentrations spacing Were the number of exposure groups/tested concentrations and dose/concentration spacing appropriate and justified by study authors (*e.g.,* to mimic a specific type of human exposure) and adequate for addressing the purpose of the study across a wide range of conditions of use (COUs) (*e.g.,* dilute, concentrated, and neat)?	
High	There were three or more dose groups tested and dose/concentration spacing were justified by study authors (*e.g.,* to mimic a specific type of human exposure) and were adequate for addressing the purpose of the study.
Medium	There were less than three group tested, however the choice of groups and diluent(s) were justified and are appropriate for common formulations. Any uncertainties given the reduced number of groups testes are minor relative to the difficulty of performing *in vivo* absorption testing.
Low	There were major limitations regarding the number of exposure groups and/or applied dose/concentration spacing (*e.g.,* dose and diluent testes are not very relevant to most exposure scenarios and only one dose/concentration tested), restricting the applicability of the results to only a subset of COUs and weight fractions.
Critically Deficient	The number of exposure groups and dose/concentrations spacing were not reported.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Test model	
Metric 11. Test animal characteristics Were the animal species, strain, sex, age, and starting body weight reported? Was the test animal from a commercial source or in-house colony? Was the test species and strain an appropriate animal model for the evaluation of the specific(s) of interest (*e.g.,* routinely used for similar study types)? Per OECD 427, male rats of 200g -250g are suitable, particularly in the upper half of this range. The most sensitive sex should be used if there is evidence that one sex is more sensitive.	
High	The test animal species, strain, sex, age, and starting body weight were reported, and the test animal was obtained form a commercial source or laboratory-maintained colony. The test species and strain were an appropriate animal model for the evaluation of dermal absorption.
Medium	Minor uncertainties in the reporting of test animal characteristics (*e.g.,* age, or starting body weight) are unlikely to have a substantial impact on results. The test animals were obtained from a commercial source in-house colony, and the test species/strain/sex was an appropriate animal model for the evaluation of dermal absorption.
Low	The source or sex of the test animal was not reported. These deficiencies are likely to have a substantial impact on results. **OR** the test animal (species, strain, sex, life-stage, source) was not the best choice for the evaluation of dermal absorption.
Critically Deficient	The test animal species and any other necessary descriptive information were not at all reported.
Not	Do not select for this metric.

Data Quality Rating	Description
Rated/Not Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 12. Adequacy and consistency of animal husbandry conditions	
High	All husbandry conditions were reported (*e.g.,* temperature, humidity, light-dark cycle, diet, water availability) and were adequate and the same for control and exposed populations, such that the only difference was exposure.
Medium	Most husbandry conditions were reported (see High bin) and were adequate and similar for all groups. Some differences in conditions were identified among groups, but these differences were considered minor uncertainties or limitations that are unlikely to have a substantial impact on results.
Low	Husbandry conditions were not sufficiently reported to evaluate if husbandry was adequate and whether differences occurred between control and exposed populations. These deficiencies are likely to have a substantial impact on results.
Critically Deficient	There were significant differences in husbandry conditions between control and exposed groups (*e.g.,* temperature, humidity, light-dark cycle). **OR** Animal husbandry conditions deviated from customary practices in ways likely to impact study results (*e.g.,* injuries and stress due to cage overcrowding). These are serious flaws that makes the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 13. Number of animals per group Was the number of replicates per dose/concentration group appropriate for the study type and outcome analysis? OECD 427 states that "a group of at least four animals of one sex should be used for each test preparation and each scheduled termination time	
Medium	The number of animals per dose/concentration and timepoint group were reported and was appropriate (*e.g.,* acceptable data from a minimum of four animals per group, all from the same sex).
Low	The number of animals per dose/concentration and timepoint group was reported but was less than recommended by current standards and guidelines (*i.e.,* less than four animals tested or sexes were mixed). This is likely to have an impact on results. **OR** The number of replicates per dose/concentration was not reported.
Critically Deficient	The number of animals per study group was insufficient to characterize dermal absorption (*e.g.,* less than four replicates per test preparation produced acceptable data).
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Domain 5. Outcome assessment	
Metric 14. Outcome assessment methodology Did the outcome assessment methodology address or report the intended absorption measurement of interest? Was the outcome assessment methodology (including measurement technique and timing of measurement[s]) appropriate for the associated conditions of use (COUs) and the dosing scenario? Were blood, urine, feces, and exhaled air (if necessary) individually collected at sampling time? [reference guidance notes re: infinite, nondepletable doses]	
High	The outcome assessment methodology addressed the intended absorption measurement AND was sensitive for the outcome(s) of interest and followed OECD guidance documents. The selected formulations are reasonable for the chemical of interest and would result in a sufficiently conservative estimate representative of conditions of use for the chemical of interest (*e.g.,* use of IPM as a diluent). All relevant bodily fluids were collected and measured. For percent absorption calculations finite dosing is required, normally 1-5 mg/cm^2 for a solid and up to 10 µL/cm^2 for liquids of test material, unless otherwise justified
Medium	The outcome assessment methodology used partially addressed the intended outcomes(s) of interest and deviations were explained, but minor uncertainties (*e.g.,* dosing was slightly below or above the recommendations for finite or infinite scenarios, did not assess all bodily fluids) are unlikely to have a substantial impact on results. If K_p determinations are presented, they should be from infinite dose or nondepletable conditions while finite dosing is required for percent absorption calculations. For infinite dose testing of solids, occlusion is required and at least 10 mg/cm^2 of pure substance must be used to establish an undepletable dose, regardless of concentration. For infinite dose testing of liquids/dilutions, occlusion is required, and flux must remain constant and steady-state throughout the duration of the experiment. K_p/flux measurements *in vivo* have substantial uncertainties, however a medium score can be achieved if efforts are taken to account for mass balance and ADME throughout the body (*e.g.,* shorter timepoints for measurement, collection of several tissues/excreta, see guidance notes).
Low	Significant deficiencies in the implementation of the reported outcome assessment methodology were identified (*e.g.,* a volatile diluent was used with a volatile test substance, etc.) **OR** The outcome assessment methodology was not clearly reported and it was unclear whether methods were sensitive for the outcome of interest. This is likely to have a substantial impact on results. For K_p/flux measurements, a low is assigned if efforts were not taken to account for potential missing absorbed dose through ADME processes (*e.g.,* only one tissue measured and/or delayed measurements that did not capture immediate absorption). K_p measurements are also downgraded if it is unclear whether the applied dose is non-depletable.
Critically Deficient	The reported assessment methodology was not sensitive to the outcome(s) of interest. For example, percentage absorption was determined only from an infinite dose, and/or K_p/flux was derived from a clearly finite dose, and statistics could not easily be calculated independently, or no relevant bodily fluids/tissues were assessed. These are serious flaws that make the study unusable.
Not Rated/Not	Do not select for this metric.

Data Quality Rating	Description
Applicable	
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 15. Consistency of outcome assessment Was the outcome assessment carried out consistently (*i.e.,* using the same protocol) across study groups (*e.g.,* assessment at the same time after initial exposure in all study groups)?	
High	Details of the outcome assessment protocol were reported, and outcomes were assessed consistently across study groups (*e.g.,* at the same time after initial exposure) using the same protocol in all study groups, the duration of exposure was the same across groups, the time periods when excreta were obtained were consistent across groups, etc.
Medium	There were minor differences in the timing of outcome assessment across study groups, or incomplete reporting of minor details of outcome assessment protocol execution were explained, but these uncertainties or limitations are unlikely to have substantial impact on results.
Low	Details regarding the execution of the study protocol for outcome assessment (*e.g.,* timing of assessment across groups) were confusing, limited, or not reported nor deviations explained, and these deficiencies are likely to have a substantial impact on results.
Critically Deficient	There were large inconsistencies in the execution of study protocols for outcome assessment across study groups. These are serious flaws that make the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 16. Sampling adequacy and sensitivity Was the reported sampling size adequate for the outcome(s) of interest, including number of evaluations per exposure group, and endpoint (*e.g.,* scintilliation counts/sample)?	
High	The study reported adequate sampling for the outcome(s) of interest including number of evaluations per exposure group, and measurement sensitivity (*e.g.,* scintillation counts/sample and/or duration of radioactivity detection, adequate signal to noise [*i.e.,* background] ratio for detection [*e.g.,* signal 3× noise]). The sampling intervals should be adequate to allow estimation of dermal absorption.
Medium	Details regarding sampling were reported, but minor limitations were identified in the reported sampling of the outcome(s) of interest and were explained. However, those limitations are unlikely to have a substantial impact on results.
Low	Details regarding sampling of outcomes were not fully reported nor explained and the omissions are likely to have a substantial impact on results.
Critically Deficient	Reported sampling was not adequate and/or serious uncertainties or limitations were identified in how the study carried out the sampling of the outcome(s) of interest (*e.g.,* replicates from control and test concentrations were evaluated at different times).
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's	*[Document concerns, uncertainties, limitations, and deficiencies and any additional*

Data Quality Rating	Description
Comments	*comments that may highlight study strengths or important elements such as relevance]*
Domain 6. Confounding/variable control	
Metric 17. Confounding variables in test design and procedures Were there confounding differences among the study groups that could influence the outcome assessment (*e.g.,* differences in size of skin area exposed to the chemical, differences in test substance lot or batch that might have different purities)?	
High	There were no reported differences among study group parameters (*e.g.,* test substance lot or batch, initial starting weights) that could influence the outcome assessment.
Medium	Although the study did not report all information to determine whether confounding bias may exist, reported information did not identify differences (or identified only minor differences) among study groups in the above listed confounding factors. Minor differences were reported and explained in initial conditions that are unlikely to have a substantial impact on results.
Low	Reported information indicated moderate differences among the study groups with respect to body weight changes or other differences that may be attributed to systemic toxicity, or there were other major inconsistencies across study groups (*e.g.,* body weight variation was greater than 20% compared to mean).
Critically Deficient	There were significant differences among the study groups with respect to above considerations that make the data unreliable (*e.g.,* exposed skin was excessively hairy in one rodent compared to another, clear signs of damaged skin in some animals due to experimental procedures.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 18. Confounding variables in outcomes unrelated to exposure Were there differences among the study groups unrelated to exposure to test substance (*e.g.,* solubility in formulation) that could influence the outcome assessment? Were there differences among the study groups in animal attrition or health outcomes unrelated to exposure (*e.g.,* infection, damaged tissue) that could influence the outcome assessment? Professional judgement should be used to determine whether such differences would invalidate the study.	
High	There were no reported differences among the study animals or groups in test model unrelated to exposure (*e.g.,* solubility in formulation). Details regarding animal attrition and health outcomes unrelated to exposure (*e.g.,* infection, skin damage unrelated to treatment) were reported for each study group and there were no differences among groups that could influence the outcome assessment.
Medium	Authors reported that one or more animals or groups experienced disproportionate outcomes unrelated to exposure (*e.g.,* solubility issues, formulation-specific irritation), but data from the remaining exposure replicates or groups were valid and is unlikely to have a substantial impact on results. **OR** There was no information either to support or dismiss the suggestion that there were differences among groups in animal attrition, health outcomes unrelated to exposure, or solubility that could influence the outcome assessment.
Low	Data on outcome differences unrelated to exposure (*e.g.,* technical errors or variation in

Data Quality Rating	Description
	isolation of bodily fluids across test groups) were not reported for each study replicate or group and the missing information is likely to have a substantial impact on results.
Critically Deficient	There is evidence of insolubility in the formulation such that it was not properly demonstrating a diluted solution. **OR** Reported information indicated that study groups experienced attrition (*e.g.,* premature death) or health outcomes unrelated to exposure (*e.g.,* infection) that would render the full study (*i.e.,* all dose groups) unreliable considering the short-term duration.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 7. Data presentation and analysis	
Metric 19. Data analysis Were statistical methods, calculations methods, and/or data manipulation clearly described and appropriate for dataset(s)? Were absorption estimates **presented** ~~measured~~ across a time series for each compartment of the test system? **Did the results vary widely?**	
High	Statistical methods (including any calculations or data transformations) were clearly described or had only minor omissions and were appropriate for the dataset(s). Percent~~age~~ absorption estimates were measured across a time series for each compartment of the test system, and K_p/flux measurements were based on the linear/steady-state part of the absorption curve. Calculated absorption estimates properly accounted for outliers consistently across replicates/timepoints. **The coefficient of variation (CV) was ≤25% across samples, timepoints, dose groups in an individual experiment.**
Low	Statistical analysis was performed but not described adequately to understand what was performed or whether it was properly applied (*e.g.,* determination of outliers) **or** statistical analysis was inconsistently/inappropriately applied across replicates and datasets (*e.g.,* ~~absorption not measured across time series,~~ inconsistent exclusion of outliers {perhaps due to integrity failure} across measurements ~~but coefficient of variation for several replicates (SD relative to mean) was < 25%~~). **OR** Absorption estimates were not presented across a time series for each **scenario** ~~component~~. **OR** **[The CV was >25% and ≤50% for more than half the samples across animals, replicates, media (*e.g.,* receptor fluid, timepoints) within an individual scenario in a study.] OR [The CV was >50% for more than half the samples within an individual scenario in a study, and data** are **available for EPA to calculate an alternate (upper end) value to account for variability in the results.]**
Critically Deficient	Statistical analysis was performed using an inappropriate method (*e.g.,* parametric test for non-normally distributed data) ~~and/or coefficient of variation for several replicates (SD relative to mean) was >25%.~~ **OR** Statistical analysis was not performed. **OR The coefficient of variation (CV) was >50% for more than half the samples (*e.g.,* across samples, timepoints, dose groups) for an individual experiment.** **AND** Data enabling an independent statistical analysis **or to calculate an upper end value for**

Data Quality Rating	Description
	fraction absorbed/K_p were not provided. These are serious flaws that make the study unusable.
Not Rated/Not Applicable	Statistical analysis was not possible (n = 1−2) or not necessary **(clearly negative findings across all groups).**
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 20. Data interpretation Is the interpretation of results consistent with standards and guidelines? For example, did reported absorption estimates account for sufficient recovery? Was the combined amount of test substance in the skin (after removing appropriate tape strips if tape strips were used), blood, tissues, excreta, carcass and cage wash counted in the overall estimate? Was K_p vs. fractional absorption results derived from the appropriate exposure conditions (infinite dose vs finite dose, respectively)?	
High	Recovery of applied test substance was adequate (mean of 100% ± 10% or ± 20% for volatile chemicals; recoveries outside this range must be justified) or the absorption estimate was normalized to account for any reduction below these levels. Both the skin compartment and any tape-stripping washes after the first two were included in the absorption estimate. **AND** Assay results were correctly interpreted relative to the properties of the test substance and the assay setup (sufficient duration to capture all absorption if not evaporated, proper interpretation of finite vs infinite dose).
Medium	Absorption estimates were calculated improperly or incompletely (*e.g.,* skin compartment not included, values not normalized if recovery less than adequate), however simple independent data analysis is possible to overcome these issues.
Low	There are major uncertainties based on insufficient or incorrect interpretation of the results by the authors (*e.g.,* characterization of infinite vs finite doses), however EPA is able to estimate results with some level of confidence.
Critically Deficient	The reported scoring and/or evaluation criteria were very inconsistent with established practices, resulting in the interpretation of data results that are seriously flawed and highly misleading relative to the properly interpreted results (*e.g.,* study author claims 5% absorption but correct analysis results in 40% absorption; only percentage absorption **but not flux** is reported for **an infinite** ~~a finite~~ dose) and therefore not usable for any scenarios **AND** EPA is unable to confidently interpret the correct results based on the reported data.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 21. Reporting of data Were the data for all outcomes presented? Were data reported by exposure group? Per OECD 427, data should be presented as dislodgeable dose, skin compartment, blood concentration, excreta/expired air, and quantity remaining in carcass or removed organs. Irritation should also be reported if identified.	
High	Data for exposure-related findings were presented by exposure group (*e.g.,* all timepoints, formulations, concentrations, finite vs. infinite dose) and tissue compartments/bodily fluids of interest. Negative findings were reported qualitatively or quantitatively.
Medium	Data for exposure-related findings were reported for most, but not all, treatment levels (all

Data Quality Rating	Description
	tissue compartments/bodily fluids). The minor uncertainties in outcome reporting are unlikely to have substantial impact on results (*e.g.,* intermediate timepoints not included in the data tables but the full curve is included).
Low	Data for exposure-related findings were not shown for each treatment group, but results were described in the text. **OR** Data were reported inconsistently or with errors, however EPA was able to interpret the correct results with some level of confidence. **OR** Continuous data were presented without measures of variability or n/group.
Critically Deficient	Data presentation was inadequate (*e.g.,* the report does not differentiate among findings in multiple exposure groups) **OR** Major inconsistencies were present in reporting of results that render the findings unreliable and EPA is unable to confidently fill in gaps or make assumptions to make up for these uncertainties.
Not Rated/Not Applicable	Do not use for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

5.6.2 Data Quality Metrics – *In Vitro/Ex Vivo*

Table 5-10 presents the *in vitro/ex vivo* dermal absorption data evaluation criteria, as modified since publication of Appendix S of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). Language that was inserted is **bolded** and language removed is shown as ~~strikethrough~~. EPA used OECD guidelines to develop and update the criteria for the evaluation of *in vitro/ex vivo* dermal absorption references (OECD, 2022, 2011, 2004a, c). For metrics 1, 3, 5, 6 and 10 to 21, EPA made changes to the wording were made to provide context and/or clarity to the evaluation question and/or metric rankings. For metrics 4, 5, 7, and 10, language was added in the places that were marked as TBD in Appendix S of U.S. EPA (2021). For metric 4, the wording originally used for the medium ranking was changed to indicate a high ranking and wording was added to the medium ranking. EPA also updated the low and critically deficient ranking descriptions. For metric 8, EPA removed the high ranking, and the description was incorporated into the medium ranking. EPA updated metric 19 to address data variability (the coefficient of variation) and revised metric 20 to clarify language and consider whether the reference calculated appropriate values (K_p/flux vs. fraction absorbed). The full set of *in vitro/ex vivo* data quality metrics are shown below.

Table 5-10. Updated Data Evaluation Criteria for *In Vitro/Ex Vivo* Dermal Absorption Studies

Data Quality Rating	Description
Domain 1. Test substance	
Metric 1. Test substance identity Was the test substance identified definitively (*i.e.,* established nomenclature, CASRN, physical nature, physical and chemical properties, and/or structure reported, including information on the specific form tested [*e.g.,* salt or base, valence state, isomer, if Applicable] for materials that may vary in form)? If test substance was a mixture, were mixture components and ratios characterized?	
High	The test substance (*i.e.,* chemical of interest) was identified definitively (*i.e.,* nomenclature, CASRN, structure) and where Applicable the specific form (*e.g.,* particle characteristics for solid state materials, salt or base, valence state, hydration state, isomer, radiolabel, etc.) was definitively and completely characterized. For mixtures, the components and ratios were characterized (*i.e.,* provided as concentration, ratio of percentage of the mixture or product). Additionally, for radiolabeled substances, the location of the radiolabel within the substance should be indicated, ideally with **the radiolabel** ^{14}~~C~~ in a metabolically stable position.
Medium	The test substance (*i.e.,* chemical of interest) was identified and the specific form was characterized (where Applicable). For mixtures, some components and components and ratios were identified and characterized but at least the chemical of interest has a percentage/concentration reported. There were minor uncertainties (*e.g.,* minor characterization details were omitted **such as about the** radiolabel ~~details~~) that were unlikely to have a substantial impact on results.
Low	The test substance and form (if Applicable) were identified, and the components and ratios of mixtures were characterized, but there were uncertainties regarding test substance identification or characterization that are likely to have a substantial impact on the results (*e.g.,* no information on isomer (or enantiomer) composition of differences could affect toxicokinetic properties, limited particle size information, omitted details regarding branched or straight chain structure).
Critically Deficient	The test substance identity and form (the latter if Applicable) could not be determined from the information provided (*e.g.,* nomenclature was unclear and CASRN or structure were not reported) OR For mixtures, the components and ratios were not characterized.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 2. Test substance source Was the source of the test substance reported, including manufacturer and batch/lot number for materials that may vary in composition? If synthesized or extracted, was test substance identity verified by analytical methods?	
High	The source of the test substance was reported as a manufacturer or the production process was specifically identified. The batch/lot number was identified (for materials that may vary in composition), and the chemical identity was either certified by the source in the publication or could be verified on a manufacturer's website. OR The test substance identity was analytically verified by the laboratory that performed the toxicity study.

Data Quality Rating	Description
Low	The test substance was synthesized or extracted by a source other than the manufacturer [and no production process was identified]. OR The source was not reported. AND The test substance identity was NOT analytically verified by the performing laboratory.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 3. Test substance purity Was the purity or grade (*i.e.,* analytical, technical) of the test substance (including the radiolabeled substance) reported and adequate? Were impurities identified? Were impurities present in quantities that could influence the results?	
High	For discrete substances, the test substance **(including radiolabel)** purity and composition were such that any observed effects were highly likely to be due to the nominal test substance itself (*e.g.,* highly pure at >98% or analytical grade test substance or a formulation of lower purity that contains ingredients considered to be inert, such as water). All components, including impurities and residual chemicals, were identified and the chemical of interest was the main component **(including the radiolabeled portion)**.
Medium	The nature and quantity of reported impurities **(of the unlabeled and labeled portions of the chemical)** are such that study results were not likely to be substantially impacted by the impurities (impurities not known to induce outcome of interest at low levels, impurities are inert or GRAS, etc.). Regardless of the nature and purity, for discrete chemicals, the purity of the chemical of interest should be >70%, unless water is the only impurity.
Low	Purity and/or grade of test substance were not reported **(for both the labeled and unlabeled chemical)**.
Critically Deficient	The nature and quantity of reported impurities **(for unlabeled and labeled substances)** were such that study results were likely to be due to one or more of the impurities. ~~This is a serious flaw that makes the study unusable.~~ **AND/OR** **For discrete chemicals, purity (for labeled and unlabeled substances) was <70% with an impurity other than water**.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 2. Test design	
Metric 4. Reference compounds Were the results of a reference compound (*e.g.,* caffeine, testosterone, benzoic acid) run concurrently or separately and recently by the same laboratory and reported in the study? Was the absorption response appropriate? **Alternately, has the performing lab demonstrated previous technical sufficiency in dermal absorption studies?** ~~[TBD: need to decide how important it is to have reference compounds]~~	

Data Quality Rating	Description
High	**An appropriate concurrent reference compound was tested or data from a historical reference compound was provided, and an appropriate response was observed. Any uncertainties (*e.g.,* omission of minor details regarding exposure or response) are minor.**
Medium	~~When Applicable, an appropriate concurrent or historical reference compound was used, and an appropriate response was observed. Any uncertainties (*e.g.,* omission of minor details regarding exposure or response) are minor.~~ **An appropriate concurrent or historical reference compound was used, but there were some deficiencies regarding the reference compound exposure or response (*e.g.,* the response was not well described, it is unclear whether the response was acceptable).**
Low	~~When Applicable, an appropriate concurrent or historical reference compound was used, but there were deficiencies regarding the reference compound exposure or response (*e.g.,* the response was not described).~~ ~~OR~~ ~~No reference compound was used or reported.~~ **No appropriate reference compound was used or reported AND there is no established history of test performance in the performing laboratory.**
Critically Deficient	Reference compounds were run but ~~an inadequate response for the reference compounds (outside historical controls results~~) indicates ~~that the assay would not accurately measure absorption.~~ **the response was unacceptable (*e.g.,* outside historical control results), raising concerns about the validity of the assay.**
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 5. Assay procedures Were assay methods and procedures (*e.g.,* diffusion cell set up, temperature, humidity, physiological ~~conductivity~~ **compatibility** of receptor fluid, volumes applied ~~and surface area of skin~~, **amount of test substance per surface area of skin**, use/measurement of occlusion or carbon trap, materials and procedures used for tape stripping, capture of volatile compounds if required) described in detail and Applicable/justified? ~~See other metrics for additional assay procedures (*e.g.,* metrics 1–3 for test substance information; metric 11 for exposure duration; metric 15 for replicates per group).~~ **Do the study methods describe how they ensure that quantification of the receptor fluid is adequately sensitive (*e.g.,* sufficient signal-to-noise ratio, high enough specific activity of radiolabel, sufficient amount of time or number of scintillations detected).** **Diffusion cell setup should indicate static vs flow-through, and for flow-through the flow rate should be indicated.** ~~OECD 428, OECD GD28 and OECD GD156 should be consulted and used to consider quality ratings.~~	
High	Study authors described the methods and procedures (*e.g.,* diffusion cell set up, temperature, humidity, physiological ~~conductivity~~ **compatibility** of receptor fluid, volumes applied and surface area of skin, use/measurement of occlusion or carbon trap, **specific activity of radiolabel**, materials and procedures used for tape stripping, capture of volatile compounds if required) used for the test in detail **and justified any relevant choices**. Either a static cell or flow-through system was used, with either constant stirring (static cell) or an appropriate flow-rate (flow-through). **These methods were appropriate based on the TGs and GDs above**.

Data Quality Rating	Description
Medium	Methods and procedures were partially described **(*e.g.*, all but temperature and humidity are described)** but appeared to be appropriate ~~(*e.g.*, TBD)~~, so the omission of details is unlikely to have a substantial impact on results.
Low	The methods and procedures were not well described or deviated from customary practices **(*e.g.*, ~~TBD~~ absence of occlusion or carbon trap for volatile test substance)** and this is likely to have a substantial impact on results, **however conservative statistical adjustments could possibly account for these deviations**.
Critically Deficient	Assay methods and procedures were not appropriate **and would result in unusable data that cannot be statistically accounted for** (*e.g.*, ~~TBD~~ **failure to use a diffusion cell with sufficient seal, too low volume/mass of test substance applied per surface area, tape stripping and wash fractions combined and not measured independently)**.
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 6. Standards for tests For assays with established criteria, were the test validity, acceptability, reliability, and/or QC criteria reported and consistent with current standards and guidelines? **Were sufficient data provided to determine that the standards/guidelines have been met?** Example criteria: *Percent recovery:* 100 ± 10% of the radioactivity as stated in OECD TG 428; 100±20% for volatile and unlabeled compounds as stated in OECD GD 28. ***Coefficient of Variation*: Variance across replicates should be measured and indicated when standard deviation exceeds 25%.** ***Skin integrity:* (1) Tritiated water – a.) a 'limit value' for a maximum K_p of 4.5E−03 cm/h (Guth et al. 2015 [Tox In Vitro 29:113-23]; Meidan and Roper, 2008 [Tox In Vitro 22:1062-9]) and mean K_p of 2.5E−03 cm/h (Bronaugh et al. 1986 [Br J Dermatol 115:1-11]) for human *ex vivo* skin and b.) percent absorption (≤0.6% of applied dose in 1 hour) (Learn et al.– Poster from Charles River Labs).** **(2) Electrical conductance - minimal threshold of 17 kilo-ohms (Fasano et al., 2002) [Tox In Vitro 16:731-740]). (3) Trans-epidermal water loss - Less than 10 grams/m^2/h (Zhang, 2018) [Tox In Vitro 51: 129-135] (4) Other internal reference standard methods (*e.g.*, 3H-labeled compounds, methylene blue) as cited in Guth et al. 2015.** **See Guidance for Reviewers to view examples of various criteria.** ~~*Skin integrity:* (1) Tritiated water – minimal flux threshold TBD (2) Electrical conductance - minimal threshold of 17 kilo-ohms (Fasano et al., 2002).~~ ~~OECD 428, OECD GD28, and OECD GD156 should be consulted; deviations should be explained.~~	
Medium	**Criteria used to determine the** ~~The test~~ validity acceptability, reliability, and/or **quality of the experiment** ~~QC criteria~~ (*e.g.*, threshold for skin integrity, percent recovery considered acceptable) were reported and consistent with current standards and guidelines, as/if Applicable **and authors stated that results met those criteria or the results provided enough detail to compare with the criteria**.

Data Quality Rating	Description
Low	**Few or no QC criteria were reported, however, the reported results provided enough information to evaluate how the study compared against the criteria stated in the study and/or external criteria and standards.** ~~Some QC criteria were not reported~~.
Critically Deficient	Inadequate **information was provided on the standards used to evaluate the study results AND (1) the authors did not report whether the test met pre-established criteria, OR (2) inadequate** data **on results** were **presented** ~~provided~~ to demonstrate **the** validity, acceptability, and reliability of the test when compared with current standards and guidelines **or the pre-established standards/criteria identified by the authors. In this case, adequate QC cannot be performed.**
Not Rated/Not Applicable	Do not select for this metric
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 3. Exposure characterization	
Metric 7. Preparation and storage of test substance (chemical) Did the study characterize preparation of the test substance and storage conditions? Were the frequency of preparation and/or storage conditions appropriate to the test substance stability and solubility (if Applicable)?	
High	The test substance preparation and/or storage conditions (*e.g.,* test substance stability, homogeneity, mixing temperature, stock concentration, stirring methods, storage conditions) were reported and appropriate for the test substance (*e.g.,* stability and solubility in diluents or solvents confirmed especially if they differ from what is used commercially; volatile test substances prepared and stored in sealed containers; same stock solution for all exposure concentrations).
Medium	The test substance preparation and storage conditions were reported, but minor limitations in the test substance preparation and/or storage conditions were identified (*e.g.,* **test substance formulations were stirred instead of centrifuged for a specific number of rotations per minute** ~~TBD~~). OR There is an omission of details that are unlikely to have a substantial impact on results (*e.g.,* preparation/administration of test substance is described, but storage is not reported; however, storage is unlikely to affect results based on likely stability over the time frame of the test or the physical and chemical properties of the chemical make concerns about volatility or solubility unlikely).
Low	Deficiencies in reporting of test substance preparation, and/or storage conditions are likely to have a substantial impact on results (*e.g.,* available information on physical and chemical properties suggests that stability and/or solubility of test substance in diluent/solvent may be poor). OR Information on preparation and storage was *not* reported and lack of details could substantially impact results (*e.g.,* preparation for volatile or low-solubility chemicals).
Critically Deficient	Serious flaws reported regarding test substance preparation and/or storage conditions will have critical impacts on dose/concentration estimates and make the study unusable (*e.g.,* instability of test substance, test substance volatilized rapidly from storage containers).
Not Rated/Not Applicable	Do not select for this metric

Data Quality Rating	Description
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 8. Consistency of exposure administration Were exposures administered consistently across study groups (*e.g.,* consistent volumes and area of skin surface for application)?	
~~High~~	~~Details of exposure administration were reported and exposures were administered consistently across study groups in a scientifically sound manner (*e.g.,* consistent volumes, thickness and area of skin surface for application,).~~
Medium	Details of exposure administration were reported or inferred from the text, **and** ~~but the minor limitations in administration of~~ exposures **were administered consistently across study groups in a scientifically sound manner** (*e.g.,* **consistent volumes** ~~slight variation in volume~~, thickness and area **of** ~~or~~ skin surface ~~used~~ for application). **Any minor deviations/limitations are considered)** ~~that were identified~~ are unlikely to have a substantial impact on results. OR Details of exposure administration are incompletely reported, but the missing information is unlikely to have a substantial impact on results.
Low	Details of exposure administration were reported, but deficiencies in administration of exposures (*e.g.,* moderate differences in volume, thickness, and area of skin surface used for application) that were reported or inferred from the text are likely to have a substantial impact on results. OR Details of exposure administration are insufficiently reported and the missing information is likely to have a substantial impact on results
Critically Deficient	Exposures were not administered consistently across and/or within study groups (*e.g.,* large differences in volume, thickness, and area of skin surface used for application) resulting in serious flaws that make the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 9. Reporting of concentrations Were exposure doses/concentrations or amounts of test substance reported without ambiguity (*e.g.,* point estimate instead of range, analytical instead of nominal)? Note: Ambiguity also applies to doses/concentrations if values were only reported as points on a figure without numerical values.	
High	The exposure doses/concentrations or amounts of test substance were reported without ambiguity (*e.g.,* point estimate instead of range, analytical/measured instead of nominal).
Medium	The exposure doses/concentrations or amounts of test substance were reported with some ambiguity (*e.g.,* range instead of point estimate OR nominal instead of analytical/measured).
Low	The exposure doses/concentrations or amounts of test substance were reported but with substantial ambiguity about precision (*e.g.,* only an estimated range AND only nominal instead of analytical measurements).
Critically Deficient	The exposure doses/concentrations or amounts of test substance were not reported, resulting in serious flaws that make the study unusable.

Data Quality Rating	Description
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 10. Exposure duration Was the exposure duration (*e.g.,* hours) reported and was it appropriate for this study type and/or outcome(s) of interest? **Was the duration of exposure relevant to conditions of use and physical-chemical properties of the test substance? Did measurements continue post-exposure to account for retained dose in skin?** ~~[TBD: add text about human exposure relevancy]~~.	
High	The exposure duration (*e.g.,* hours) was reported and was appropriate for the study type and/or outcome(s) of interest (*e.g.,* at least 6–10 hours prior to washing and up to at least 24 hours **total including** post-washing). A shorter exposure duration may also be included but is less useful unless the substance is demonstrated to be volatile, **the results demonstrate that absorption approached completion (*e.g.,* nothing left in the skin wash or tape strip samples),** or the timepoint is used only for K_p/flux measurements.
Low	The duration(s) of exposure differed slightly from current standards and guidelines for studies of this type (*e.g.,* <6 to 10 hours prior to washing and less than 24 hours **total including** post-washing), **and** ~~but~~ the differences **may** ~~are unlikely to~~ have a substantial impact on results.
Critically Deficient	No information on exposure duration(s) was reported OR the exposure duration was not appropriate OR Duration(s) differed significantly from studies of the same or similar types **and these differences (most likely shorter duration)**. ~~These deficiencies~~ are likely to have a substantial impact on **interpretation of** results.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 11. Number of exposure groups and concentrations spacing Were the number of exposure groups/**tested concentrations** and dose/concentration spacing **appropriate and** justified by study authors (*e.g.,* to mimic a specific type of human exposure) and adequate for addressing the purpose of the study **across a wide range of conditions of use (COUs) (*e.g.,* dilute, concentrated, and neat)?**(*e.g.,* to evaluate dermal absorption)?	
High	**There were three or more dose** ~~The number of exposure~~ groups **tested** and dose/concentration spacing were justified by study authors (*e.g.,* to mimic a specific type of human exposure) and **were** ~~was~~ adequate for addressing the purpose of the study.
Low	There were ~~minor~~ limitations regarding the number of exposure groups and/or applied dose/concentration spacing (*e.g.,* unclear if lowest dose was low enough or the highest dose was high enough, **or less than three doses/concentrations tested), restricting the applicability of the results to only a subset of COUs and weight fractions**~~.), but the number of exposure groups and spacing of exposure levels were adequate and are unlikely to have a substantial impact on results.~~

Data Quality Rating	Description
Critically Deficient	The number of exposure groups and dose/concentration spacing were not reported ~~OR~~ ~~the number of exposure groups and dose/concentration spacing were not adequate and did not mimic expected human exposures.~~
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 4. Test model	
Metric 12. Test model **(skin)** Were the test models (*e.g.,* viable skin, cadaver/cosmetic surgery skin, **animal skin**) and descriptive information (*e.g.,* tissue origin, anatomical site, tissue storage, **initial** integrity or viability) reported? What was the source of the test model? Was the model routinely used for the outcome of interest? For example, for human skin, split thickness (200–400µm), dermatomed skin is preferred.	
High	The test model (*e.g.,* viable skin, cadaver skin, cosmetic surgery **skin, animal** skin) and descriptive information (*e.g.,* tissue origin, anatomical site, tissue storage, integrity or viability, **lot/batch used**) were reported and the test model was routinely used for the outcome of interest.
Low	The test model was **insufficiently** reported **and reporting** ~~along~~ with limited descriptive ~~information.~~ ~~OR~~ ~~The test model was routinely used for the outcome of interest. Reporting~~ limitations **may** ~~are unlikely to~~ have a substantial impact on results.
Critically Deficient	The test model and necessary descriptive information were not **at all** reported OR the test model was not appropriate for evaluation of the specific ~~outcome of interest~~
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 13. Number/Replicates per group Was the number of replicates per dose/concentration group appropriate for the study type and outcome analysis?	
Medium	The number of replicates per dose/concentration were reported and was appropriate (*e.g.,* acceptable data from a minimum of four replicates per test preparation).
Low	The number of replicates per dose/concentration **and timepoint** was reported but was less than recommended by current standards and guidelines **(*i.e.*, less than four replicates for each test preparation according to OECD TG 428)**. This is likely to have an impact on results. OR The number of replicates per dose/concentration was not reported.
Critically Deficient	The number of organisms or tissues per study group and/or replicates per study group was insufficient to characterize dermal absorption (*e.g.,* less than four replicates per test preparation produced acceptable data).

Data Quality Rating	Description
Not Rated/Not Applicable	**Do not select for this metric.** ~~Not Applicable for qualitative studies not requiring any statistics.~~
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 5. Outcome assessment	
Metric 14. Outcome assessment methodology Did the outcome assessment methodology address or report the intended outcome(s) of interest? Was the outcome assessment methodology (including ~~nature of endpoints evaluated~~, measurement technique and timing of measurement[s]) **appropriate** ~~sensitive~~ for the **associated conditions of use (COUs)**~~outcome(s) of interest (*e.g.*, measured endpoints that are able to detect a true effect~~)? OECD 428, OECD GD28 and **the dosing scenario?** ~~OECD GD156 should be consulted, and deviations should be documented and explained.~~	
High	The outcome assessment methodology addressed the intended outcome(s) of interest AND was sensitive for the outcome(s) of interest and followed OECD guidance documents. The **selected formulations are reasonable for the chemical of interest and would result in** ~~dosing reflected~~ a **sufficiently conservative estimate representative** ~~range~~ of conditions of use **for the chemical of interest (*e.g.*, use of IPM diluent).** ~~(COUs) to which humans are exposed~~. The infinite dose scenario **should be used** ~~is optimum~~ for K_p determinations while finite dosing is **required** ~~optimal~~ for **percent**~~%~~ absorption calculations. **For finite**~~The~~ dose **conditions, normally 1–5 mg/cm² of** ~~in the~~ **skin for a solid, and up to 10 µL/cm² for liquids of test material should be loaded, unless otherwise justified. For dilutions (*i.e.*, not neat test material), finite** ~~should be considered to be the potentially absorbable~~ dose **testing for each concentration of should ideally be conducted with application of 10 µL/cm² test material. For infinite dose testing of solids, it is required that at least 10 mg/cm² of pure substance be used to establish an undepletable dose, regardless of concentration. For infinite dose testing of liquids, at least 100 µL/cm² of pure substance should be used** to **establish an undepletable dose, regardless of concentration.** ~~calculate the final % absorption. Recovery is 90±10% or 80±20% for volatile substances.~~
Medium	The outcome assessment methodology used partially addressed the intended outcomes(s) of interest and deviations were explained, ~~(*e.g.*, mutation frequency evaluated in the absence of cytotoxicity in a gene mutation test)~~, but minor uncertainties **(*e.g.*, dosing was slightly below or above the recommendations for finite or infinite scenarios)** are unlikely to have a substantial impact on results.
Low	Significant deficiencies in the implementation of the reported outcome assessment methodology were identified (*e.g.*, **a volatile diluent was used with a volatile test substance** ~~matrix/assay interference, assay yielded anomalous results~~, etc.) **OR** The outcome assessment methodology was not clearly reported and it was unclear whether methods were sensitive for the outcome of interest. This is likely to have a substantial impact on results.
Critically Deficient	The reported assessment methodology was not sensitive to the outcome(s) of interest. For example, **percentage absorption was determined only from an infinite dose, and**/~~the reported measurement endpoint(s)~~ or **K_p/flux was derived from a finite dose, and statistics could** ~~timing were~~ not **easily be calculated independently.** ~~sensitive for the outcome(s) of interest (*e.g.*, cells were evaluated for chromosomal aberrations immediately after exposure to the test substance instead of after post-exposure incubation period).~~ These are serious flaws that make the study unusable.

Data Quality Rating	Description
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 15. Consistency of outcome assessment Was the outcome assessment carried out consistently (*i.e.,* using the same protocol) across study groups (*e.g.,* assessment at the same time after initial exposure in all study groups)?	
High	Details of the outcome assessment protocol were reported and outcomes were assessed consistently across study groups (*e.g.,* at the same time after initial exposure) using the same protocol in all study groups. All study groups utilized the same **vehicle for the** blank formulation as **for the study concentration groups** ~~a vehicle~~, the duration of exposure was the same across groups, the same receptor fluid composition was **used** ~~utilized~~ for each group, the sampling period was consistent across groups, etc.
Medium	There were minor differences in the timing of outcome assessment across study groups, or incomplete reporting of minor details of outcome assessment protocol execution were explained, but these uncertainties or limitations are unlikely to have substantial impact on results.
Low	Details regarding the execution of the study protocol for outcome assessment (*e.g.,* timing of assessment across groups) were confusing, limited, or not reported nor deviations explained (or cited to another publication with no description in the paper itself), and these deficiencies are likely to have a substantial impact on results.
Critically Deficient	There were large inconsistencies in the execution of study protocols for outcome assessment across study groups. These are serious flaws that make the study unusable.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 16. Sampling adequacy **and sensitivity** Was the reported sampling size adequate for the outcome(s) of interest, including number of evaluations per exposure group, and endpoint (*e.g.,* **scintillation counts/sample)?**~~number of slides/cells/metaphases evaluated per test concentration)? OECD 428, OECD GD28, and OECD GD156 should be consulted, deviations should be explained.~~	
High	The study reported adequate sampling for the outcome(s) of interest including number of evaluations per exposure group, and **measurement sensitivity** ~~endpoint~~ (*e.g.,* scintillation counts/sample **and/or duration of radioactivity detection, adequate signal to noise [*i.e.,* background] ratio for detection [*e.g.,* signal 3x noise**]). The sampling intervals should be adequate to allow accurately graphically representing the results of the receptor fluid content of the test article vs. time.
Medium	Details regarding sampling for the outcome(s) of interest were reported, but minor limitations were identified in the reported sampling of the outcome(s) of interest and were explained. However, those limitations are unlikely to have a substantial impact on results.
Low	Details regarding sampling of outcomes were not fully reported nor explained and the omissions are likely to have a substantial impact on results.

Data Quality Rating	Description
Critically Deficient	Reported sampling was not adequate for the outcome(s) of interest and/or serious uncertainties or limitations were identified in how the study carried out the sampling of the outcome(s) of interest (*e.g.,* replicates from control and test concentrations were evaluated at different times).
Not Rated/Not Applicable	**N/A** ~~NA~~ should be used for assays/studies that do not require a certain number of slides/cells/metaphases etc. be sampled for scoring (*i.e.,* mutagenicity assays, mechanistic studies).
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 6. Confounding/variable control	
Metric 17. Confounding variables in test design and procedures Were there confounding differences among the study groups in the size, and/or quality of tissues exposed that could influence the outcome assessment, **(*e.g.*, skin integrity)**?	
High	There were no differences reported among study group parameters (*e.g.,* test substance lot or batch, strain/batch/ lot number of ~~organisms~~ ~~or models used per group or size~~ **skin samples used per group or size**, and/or quality of tissues exposed) that could influence the outcome assessment. Skin integrity was ~~acceptable~~ **measured by preferable methods (*e.g.*, electrical resistance and TEWL). Results of skin integrity testing were acceptable for all replicates and exposure groups (*e.g.*, >17 kilo-ohms based on electrical resistance, less than 10 grams/m^2/h)**
Medium	Minor differences were reported and explained in initial conditions that are unlikely to have a substantial impact on results (*e.g.,* tissues from two different lots were used and QC data were similar for both lots). Skin integrity ~~had variability but were acceptable~~ **was measured by a less desirable method (*e.g.*, tritiated water) , but results were acceptable (*e.g.*, a 'limit value' for K_p of 4.5E−03 cm/h or percent absorption of ≤0.6% of applied dose in 1 hou).** Outliers were statistically evaluated. **Most results of skin integrity testing were acceptable, and the number of replicates/donors was adequate after excluding any unacceptable results.**
Low	Initial strain/batch/lot number skin samples used per group, size, and/or quality of tissues exposed was not reported. These deficiencies are likely to have a substantial impact on results.
Critically Deficient	There were significant differences among the study groups with respect to the strain/batch/lot number of ~~organisms or models used per group or size and/or quality of tissues exposed (*e.g.,* initial number of viable bacterial cells were different for each replicate [105 cells in replicate 1, 108 cell in replicate 2, and 103 cells in replicate 3], tissues from two different lots were used for *in vitro* skin corrosion test, but the control batch quality for one lot was outside of the acceptability range). Skin integrity results were below thresholds. Recovery was below guidance limits or not quantified. Exposures did not reflect worker COUs.~~ **skin samples used per group or size and/or quality of tissues exposed (*e.g.*, several replicates demonstrated integrity issues).** **Recovery varied greatly among replicates (*i.e.*, >10%). In this situation, results are not reliable for estimating actual absorption.**
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

Data Quality Rating	Description
Metric 18. Confounding variables in outcomes unrelated to exposure Were there differences among the study groups unrelated to exposure to test substance (*e.g.,* **solubility in receptor fluid** ~~contamination~~) that could influence the outcome assessment? Did the test material interfere in the assay (*e.g.,* altering fluorescence or absorbance, signal quenching by heavy metals, altering pH, solubility, or stability issues)?	
High	There were no reported differences among the study replicates or groups in test model unrelated to exposure (*e.g.,* **solubility in receptor fluid** ~~contamination~~) and the test substance did not interfere with the assay (*e.g.,* signal quenching by heavy metals). The test substance was demonstrated to be soluble in the receptor fluid.
Medium	Authors reported that one or more replicates or groups experienced disproportionate outcomes unrelated to exposure (*e.g.,* **solubility issues** ~~contamination~~), but data from the remaining exposure replicates or groups were valid and is unlikely to have a substantial impact on results. OR The test material interfered in the assay, but the interference did not cause substantial differences among the groups. OR Solubility in the receptor fluid was not demonstrated, but solubility is not likely to be an issue based on the expected concentration relative to the receptor fluid formulation.
Low	Data on outcome differences unrelated to exposure (including receptor fluid formulation) were not reported for each study replicate or group and the missing information is likely to have a substantial impact on results. OR Assay interference was present or inferred resulting in large variabilities among the groups.
Critically Deficient	There were indications of assay interference several replicates or groups or there is evidence of insolubility in the receptor fluid such that no outcomes could be assessed.
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Domain 7. Data presentation and analysis	
Metric 19. Data analysis Were statistical methods, calculations methods, and/or data manipulation clearly described and appropriate for dataset(s)? **Were absorption estimates presented across a time series for each compartment of the test system? Did the results vary widely?**	
High	Statistical methods (including any calculations or data transformations) were clearly described or had only minor omissions and were appropriate for the dataset(s). Percent~~age~~ absorption estimates were presented across a time series for each compartment of the test system, and K_p/flux measurements were based on the linear/steady-state part of the absorption curve. **Calculated absorption estimates properly accounted for outliers consistently across replicates/timepoints. The coefficient of variation (CV) was <25% for more than half of the samples across each individual scenario (across donors, replicates, media (*e.g.,* receptor fluid), timepoints) within the study.** ~~Any selection of outliers was justified.~~

Data Quality Rating	Description
Low	Statistical analysis was performed but not described adequately to understand what was performed or whether it was properly applied (*e.g.,* determination of outliers) **or** statistical analysis was inconsistently/inappropriately applied across replicates and datasets (*e.g.,* ~~absorption not measured across time series,~~ inconsistent exclusion of outliers **{perhaps due to integrity failure}** across measurements~~, coefficient of variation for several replicates (SD relative to mean) was <> 25%~~). **OR** **Absorption estimates were not presented across a time series for each scenario.** **OR** **[The CV was >25% and ≤50% for more than half the samples across donors, replicates, media (*e.g.,* receptor fluid, timepoints) within an individual scenario in a study**.] **OR [The CV was >50% for more than half the samples within an individual scenario in a study, and data** are **available for EPA to calculate an alternate (upper end) value to account for variability in the results.]**
Critically Deficient	Statistical analysis was performed using an inappropriate method (*e.g.,* parametric test for non-normally distributed data)~~, and/or coefficient of variation for several replicates (SD relative to mean) was >25%.~~ OR Statistical analysis was not performed. **OR The coefficient of variation (CV) was >50% for more than half the samples (across donors, replicates, media (*e.g.,* receptor fluid),** timepoints) **within an individual assay.** AND Data enabling an independent statistical analysis **or to calculate an upper end value for fraction absorbed/K_p** were not provided. These are serious flaws that make the study unusable.
Not Rated/Not Applicable	Statistical analysis was not possible (n = 1−2) or not necessary (clearly negative findings across all groups~~; Ames assay using 2-fold increase as benchmark~~).
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 20. Data interpretation **Is**~~Were the evaluation criteria reported and is~~ the interpretation of results consistent with standards and guidelines? **For example, did** reported absorption estimates account for sufficient recovery? Was the combined amount of test substance in the skin and receptor fluid counted in the overall estimate? **Was derivation of K_p vs fractional absorption applied to the appropriate exposure conditions (infinite dose vs finite dose, respectively)?**	
High	~~Study authors followed evaluation criteria for the test, and these were consistent with established practices~~ [a]. Recovery of applied test substance was adequate (90% for occluded or non-volatile substance, 80% for non-occluded, volatile ~~substance~~ **or unlabeled substance) or the absorption estimate was normalized to account for any reduction below these levels. Both the skin compartment and any tape-stripping washes after the first two were included in the absorption estimate**. **AND** Assay results were correctly interpreted relative to the properties of the test substance and the assay setup (sufficient duration to capture all absorption if not evaporated, proper interpretation of finite vs infinite dose).
Medium	Absorption estimates were reported improperly **or incompletely** (*e.g.,* skin compartment not included, values not normalized if recovery less than adequate), however simple independent data analysis is possible to overcome these issues.

Data Quality Rating	Description
Low	**There are major uncertainties based on insufficient or incorrect interpretation of the results by the authors (*e.g.*, characterization of infinite vs finite doses). However, EPA can estimate results with some level of confidence.** ~~Complex reanalysis of the data is required in order to obtain usable interpretations (*e.g.*, external outlier analysis may be required, K_p determination must be recalculated from the time series).~~
Critically Deficient	The reported **scoring**~~rating~~ and/or evaluation criteria were very inconsistent with established practices, resulting in the interpretation of data results that are seriously flawed and highly misleading relative to the properly interpreted results (*e.g.,* study author claims 5% absorption but correct analysis results in 40% absorption, only percentage absorption is reported from a finite dose) **and therefore not usable for any scenarios.**
Not Rated/Not Applicable	Do not select for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*
Metric 21. Reporting of data Were the data for all outcomes presented? Were data reported by exposure group?	
High	Data for exposure-related findings were presented for all outcomes by exposure group **(*e.g.*, all timepoints, formulations, concentrations, finite vs infinite dose)**. Negative findings were reported qualitatively or quantitatively.
Medium	Data for exposure-related findings were reported for most, but not all, outcomes by exposure group (*e.g.,* both short and long-term exposures). The minor uncertainties in outcome reporting are unlikely to have substantial impact on results **(*e.g.*, intermediate timepoints not included in the data tables but the full curve is included).**
Low	Data for exposure-related findings were not shown for each study group, but results were described in the text. OR Data were only reported for some outcomes. OR Continuous data were presented without measures of variability or n/group.
Critically Deficient	Data presentation was inadequate (*e.g.,* the report does not differentiate among findings in multiple exposure groups) **OR** Major inconsistencies were present in reporting of results that render the findings uncertain regarding hazard identification or dose- response.
Not Rated/Not Applicable	Do not use for this metric.
Reviewer's Comments	*[Document concerns, uncertainties, limitations, and deficiencies and any additional comments that may highlight study strengths or important elements such as relevance]*

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6 EVIDENCE INTEGRATION

As described in Section 7 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021), evidence integration refers to the consideration of evidence obtained from systematic review and scientific information obtained from sources that did not undergo systematic review to implement a weight of the scientific evidence approach. The weight of the scientific evidence is defined as "a systematic review method, applied in a manner suited to the nature of the evidence or decision, that uses a pre-established protocol to comprehensively, objectively, transparently, and consistently identify and evaluate each stream of evidence, including strengths, limitations, and relevance of each study and to integrate evidence as necessary and appropriate based upon strengths, limitations, and relevance" (40 CFR 702.33). The consideration of the quality and relevance of the data, while accounting for the strengths and limitations of the data, to appropriately evaluate the evidence for this supplement, is described in Section 7 of the 2021 draft protocol (U.S. EPA, 2021).

6.1 Physical and Chemical Properties

The systematic review process identified multiple data for each of the physical and chemical properties analyzed in the risk evaluation. Relevant data types used for the physical and chemical assessment are discussed in Appendix K of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). When a specific datum is cited for a given physical and chemical parameter, priority is given to data from expert-curated, peer-reviewed databases that have been identified as "trusted sources." Sources of uncertainty are discussed, when appropriate, in the risk evaluation.

6.2 Environmental Fate and Transport

Relevant data types used for environmental fate and transport assessment are listed in Table 7-1 of the Draft Systematic Review Protocol (U.S. EPA, 2021). Systematic review data as well as data gaps filled using evidence streams outside systematic review are incorporated as described in Figure 7-1 of the draft protocol (U.S. EPA, 2021). Quality of these data are determined based on whether they are measured or estimated data, and further broken down based on consistency, study design, study conditions and uncertainty (see Figure 7-2 in (U.S. EPA, 2021)).

6.3 Environmental Release and Occupational Exposure

HHCB does not persist in air and although persistent in soils and groundwater, it is not expected to be mobile in these media. Therefore, the focus of characterizing risk from HHCB environmental releases was water-related releases. To evaluate environmental releases, EPA first determined the COUs expected to significantly contribute to routine water releases. Based on the expected sources of release and modeling tools available, EPA evaluated release scenarios (RSs) that best address the COU as detailed in *Draft Environmental Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran HHCB* (U.S. EPA, 2026j).

For industrial releases, the Agency used the 2023 TRI data (U.S. EPA, 2024). In 2023, 65 facilities submitted their release information. For commercial releases, EPA relied on systematic review literature, Emission Scenario Documents (ESDs), and Generic Scenarios (GSs), to derive model input parameters for each RS. As described in the *Draft Environmental Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran HHCB* (U.S. EPA, 2026j), EPA conducted Monte Carlo simulations with 100,000 iterations and the Latin Hypercube sampling method, using the statistical distribution for each input parameter to calculate a full distribution of the final release results for each OES. EPA selected the 50th and 95th percentiles of the resulting distributions to represent central tendency and high-end releases, respectively. The number of release days were either

assumed based on professional judgement, relevant GSs or taken from a survey of fragrance processers (FCA, 2021).

For occupational exposure, EPA employed a screening strategy of identifying the occupational exposure scenarios (OESs) with the highest potential for exposures. Specifically, EPA assessed two OESs using modeling from GSs and ESDs, as described in the *Draft Human Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026k). No dermal exposure data were available for any of the OES considered in this assessment, so EPA modeled dermal loading using a flux-limited absorption model.

6.4 General Population, Consumer, and Environmental Exposure

HHCB concentrations in ambient air, surface water, sediment, soil, landfills, and biosolids were gathered and summarized within each environmental media pathway within the *Draft Physical Chemistry, Fate and Transport, Environmental Release, and Environmental Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (also referred to as "Draft HHCB Environmental Exposure Assessment TSD" (U.S. EPA, 2026j). The sources and approaches to gather monitoring data from peer-reviewed publications, government reports, and/or databases were classified as monitoring and mainly used to compare with modeling results or to support qualitative assessments. Consumer products containing HHCB were identified through review and searches of a variety of sources, such as completed assessments, and the 2016 and 2020 CDR (U.S. EPA, 2020, 2016). General population exposures were evaluated for oral exposure pathway based on environmental release data. In summary, modeled environmental release estimates were used as inputs for the general population exposure modeling.

6.4.1 General Population and Environmental Exposure: Surface, Groundwater, and Drinking Water

The Variable Volume Water Model (VVWM) in EPA's Point Source Calculator (PSC v1.05; (U.S. EPA, 2019) was used to estimate HHCB concentrations in surface water and benthic sediment from TSCA COU releases. PSC uses chemical-specific inputs (*e.g.,* K_{OC}; water column, photolysis, hydrolysis, and benthic half-lives) as well as release schedules and receiving waterbody parameters to model water column and benthic sediment concentrations.

Where available, EPA compared reported environmental monitoring data and reported environmental modeling data with EPA modeled media concentrations. Section 4.3.1.1 of the Draft HHCB Environmental Exposure Assessment TSD (U.S. EPA, 2026j) summarizes measured concentrations of HHCB within published literature for surface water and sediment. Section 4.3.1.2 presents modeled concentrations of HHCB within surface water and sediment from releases from relevant COUs. Concentrations of HHCB in surface water can lead to different exposure scenarios including ingestion of fish containing HHCB, drinking water sourced from contaminated surface water, and incidental dermal and ingestion exposures from recreational activities in surface water. Exposure scenarios were assessed using the highest concentration of HHCB in surface water based on highest release scenario, the combination of consumer and commercial products disposed of down-the-drain, and the resultant treated effluent releases from POTWs. Due to the tiered approach applied, and based on the available physical, chemical, and fate properties reviewed, incidental exposures to HHCB from ambient surface water, and inhalation exposures from ambient air were not evaluated.

When applying the PSC, certain physical and chemical parameters are used as model input variables, which are collected as a part of the fate team's assessment. The use of SR to verify physical and chemical properties of HHCB are thus relevant for exposure modeling using the VVWM-PSC. Physical-

chemical and fate properties selected by EPA for this assessment were applied as inputs to the PSC model and were sourced from parameters reviewed and described within the and *Draft HHCB Environmental Exposure Assessment TSD* (U.S. EPA, 2026j).

6.4.2 General Population and Environmental Exposure: Ambient Air

Monitoring data and physical, chemical, and fate properties were reviewed from available literature for the ambient air pathway, and are discussed in the Draft HHCB Environmental Exposure Assessment TSD (U.S. EPA, 2026j). HHCB can enter ambient air via industrial emissions and incineration of biosolids or HHCB-containing products. Volatilization from surface water may also occur but is limited (Section 2.3.6 in (U.S. EPA, 2026j)). Atmospheric persistence is low due to limited volatility and rapid photolysis (Section 2.4.1). Short atmospheric half-lives and low potential for long range transport (Section 2.4.1 in (U.S. EPA, 2026j)) indicate that, while detectable in low concentrations locally including in the Great Lakes region (Appendix D in (U.S. EPA, 2026j)), HHCB is unlikely to be widespread in ambient air. Therefore, air is not a major exposure route for environmental organisms and air exposure pathways to ecological receptors were not evaluated in this assessment.

6.4.3 General Population Exposure: Dietary, Biomonitoring and Exposure Reconstruction

Human milk biomonitoring data for HHCB was collected through systematic review. U.S. studies were prioritized to best reflect exposures specific to Americans. HHCB biomonitoring data for human milk from the systematic review monitoring literature is summarized in Section 3.3.1 (Oral Exposure via Human Milk) in *Draft Human Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026k). EPA reviewed biomonitoring studies that measured HHCB in human milk. They provide evidence of HHCB's presence in human milk and supported EPA's decision to evaluate the pathway albeit qualitatively.

6.4.4 Consumer Exposure Assessment

EPA assessed consumer exposure to HHCB for users resulting from use of consumer products (*Draft Human Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026k). Specifically, EPA applied a screening analysis through which continuous action air fresheners were identified as most likely to yield the highest exposures in comparison to other consumer TSCA COUs for HHCB. Accordingly, inhalation exposure from continuous-action air freshener use in a small room (*e.g.,* bathrooms, dorm rooms) was modeled using CEM as a bounding scenario to generate upper-end mist exposure estimates protective across COUs and exposed populations. Scenario inputs are expected to yield the highest mist inhalation for the following reasons:

- **Highest weight fraction:** Up to 1% HHCB in aerosol continuous-action air fresheners (per SDSs (Chase Products, 2025)). Non-aerosol products may have higher HHCB but were not prioritized because vapor inhalation is minor; HHCB is semi-volatile and persists less in indoor air than when aerosolized.
- **Highest use duration/frequency:** Continuous-action air fresheners emit throughout the day, exceeding intermittent spray cleaning/laundry uses.
- **Small room volume:** Use in a small bathroom, bedroom, or office yields the highest air concentrations due to rapid saturation (per Consumer Exposure Model v3.2).
- **Occupancy:** Assumes 24/7 (24 hours, 7 days a week) presence in the product room or 24/7 movement between rooms with product use for 1 year—a high-exposure, non-typical scenario.

Because the above scenario was used as a screening analysis intended to result in concentrations higher than other potential exposure scenarios, additional quantitative analyses for other scenarios were not

conducted. Only the inhalation route of exposure was assessed as there was no dermal hazard and there are no expected oral exposures from exposures to HHCB through reasonable uses of continuous action air fresheners.

Consumer products containing HHCB were identified through review and searches of a variety of sources, such as 2020 CDR (U.S. EPA, 2020), in addition to chemical safety data sheets (SDSs) identified through product-specific internet searches (U.S. EPA, 2025). Chemical weight fractions were gathered from SDSs and used to tailor COU-specific consumer exposure scenarios for products and articles identified in the consumer market.

Regarding the assessment of indoor air and dust exposures, monitoring and experimental data for HHCB were collected through systematic review. Additionally, U.S. studies published within the past 20 years were prioritized to best reflect current potential exposures to Americans. Other study types were not prioritized. Five monitoring studies were incorporated into the exposure characterization of HHCB in residential environments and were used to represent potential aggregate exposures from all sources including TSCA and non-TSCA. Specifically, studies from Api et al. (2023) and Fontal et al. (2016) were used to discuss common indoor sources of HHCB in indoor air include personal care products (*e.g.,* lotions, fragrances, tampons, lipsticks), air care, and cleaning products. Dodson et al. (2019) and Dodson et al. (2017)'s study of low-income housing in Boston, Massachusetts facilitated the discussion of increases in HHCB measured in residential indoor air and dust, respectively, following renovations. Lastly, EPA also incorporated Reiner et al. (2007)'s study of HHCB in milk from 39 Massachusetts women, indicating widespread exposure via human milk within this study population. Though experimental data were collected, this data type was ultimately not incorporated into the consumer exposure assessment, as such data was not necessary for the consumer exposure screening assessment for HHCB.

6.4.5 Other Data Sources

The exposure models relied heavily on the physical chemical and fate properties as input parameters. Sections 5.1 and 5.2 describe how the physical chemical and fate properties were selected. As mentioned previously, these physical chemical and fate parameters are used as inputs for PSC modeling of surface water concentrations of HHCB, IIOAC modeling of ambient air exposures and CEM modeling of consumer exposures. Where applicable, EPA relied on model defaults, exposure factors and activity patterns available from the EPA's *Exposure Factors Handbook* (U.S. EPA, 2017).

6.5 Environmental and Human Health Hazard

Sections 7.4 and 7.5 of the 2021 Draft Systematic Review Protocol explain how information from data sources that do or do not undergo systematic review are considered for use in risk evaluations under TSCA for evaluating environmental and human health hazard, respectively (U.S. EPA, 2021).

6.5.1 Environmental Hazard

Section 7.4.1 of the 2021 Draft Systematic Review Protocol describes how environmental hazard integration is organized into different evidence streams. The environmental hazard evidence streams for risk evaluations conducted under TSCA, as described in Table 7-8 of the 2021 Draft Systematic Review Protocol, have been updated (Table 6-1; updates are represented in bold text) to increase the level of clarity and consistency of granularity (U.S. EPA, 2021). These updated environmental hazard evidence streams more clearly reflect how apical and mechanistic hazardous endpoints (as defined by the screening PECO statement) that result from either controlled field/laboratory or uncontrolled exposure field studies are binned to better consider the relevancy of the data for the respective risk evaluation.

Table 6-1. Querying the Evidence to Organize Integration for Environmental Data and Information

Evidence Stream	Questions
Apical endpoints (controlled field/laboratory conditions)	Of the available data, are there endpoints that could have population level effects such as reproduction, growth, and/or mortality?
Mechanistic data **(controlled field/laboratory conditions)**	Is the mechanistic endpoint linked to an apical endpoint? Is it part of an AOP? If not, can you instead use it qualitatively? If a transcriptomic point of departure (tPOD) is available, is it appropriate to use quantitatively?
Apical endpoints (uncontrolled exposure field conditions)	Are there any field studies available showing adverse effects? How does exposure to the chemical of interest affect the community of organisms? Are there any co-occurring adverse environmental conditions other than exposure to the chemical of interest that should be taken into consideration?
Mechanistic endpoints (uncontrolled exposure field conditions)	**Is the mechanistic endpoint linked to an apical endpoint? Is it part of an AOP? If not, can you instead use it qualitatively? If a transcriptomic point of departure (tPOD) is available, is it appropriate to use quantitatively? Are there any co-occurring adverse environmental conditions other than exposure to the chemical of interest that should be taken into consideration?**

As described in the *Draft Human Health and Environmental Hazard Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026l), streams for environmental hazard included empirical data with apical endpoints for aquatic and terrestrial organisms that were reviewed following the TSCA systematic review process.

EPA reviewed potential environmental health hazards associated with HHCB (U.S. EPA, 2026l). Studies identified as meeting PECO screening criteria and evaluated for data quality received an overall quality determination of high, medium, low, or uninformative. EPA systematically evaluated all data for this hazard characterization, but relied upon high-quality and medium-quality studies for quantitative hazard characterization. However, references receiving an overall quality determination of low or uninformative were included in tables and descriptions to provide complete summaries of the reasonably available information. Reasons for low or uninformative ratings included experimental doses exceeding the HHCB limit of water solubility, no effects at the highest concentration tested, and/or were part of a mixture of potentially hazardous chemicals (U.S. EPA, 2026l). An OQD of high and medium were assigned to 35 aquatic studies and 14 terrestrial studies. Due to a lack of wildlife terrestrial mammalian studies, controlled laboratory studies that used rats as human health model organisms were used to assess terrestrial hazards.

Using empirical evidence streams, EPA characterized the environmental hazards of HHCB to surrogate species representing various receptor groups (U.S. EPA, 2026l), including, aquatic vertebrates (fish, acute and chronic; amphibian, acute); aquatic invertebrates (acute and chronic); aquatic algae (chronic); terrestrial invertebrates; terrestrial vertebrates (mammalian [rat]: oral routes of exposure) and terrestrial plants.

Evaluations of the strength of evidence and weight of scientific evidence for environmental hazard was conducted as described within Section 7.4.2 of the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021). For additional details on the application of this methodology, please see Appendix E of the *Draft Human Health and Environmental Hazard Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026l) and Section 4 of the *Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026m).

6.5.2 Human Health Hazard

Section 7.5 of the 2021 Draft Systematic Review Protocol describes how EPA considers individual evidence streams (human, animal toxicity, and mechanistic/supplemental studies) when integrating evidence (U.S. EPA, 2021). For risk evaluations conducted under TSCA, the human health hazard evidence streams were updated (Table 6-2) to more clearly reflect how apical and mechanistic hazard endpoints (as defined by the screening PECO statement) that result from either animal toxicology or epidemiology studies are binned to better consider the relevancy of the data for the risk evaluation.

Table 6-2. Querying the Evidence to Organize Integration for Human Health Hazard Data and Information

Evidence Stream	Questions
Studies of Exposed Humans Considered for Deriving Toxicity Values	Is there any qualitative data in human studies that can be used to support PODs used for risk estimates?
In vivo Mammalian Animal Studies Considered for Deriving Toxicity Values	Is there dose-response information and/or endpoints that could be used as PODs? Are there differences/similarities in toxicity across studies of different exposure durations and routes? Is there concordance across species and studies for observed endpoints?
Mechanistic and *In Vitro* Studies and Supplemental Information	Is the mechanistic endpoint linked to an apical endpoint? Is it part of an AOP? If not, can it be used qualitatively?

After evaluating individual studies for data quality, EPA summarized hazard information by hazard outcome and considered the strengths and limitations of individual evidence streams (*i.e.,* human studies of apical (phenotypic) endpoints if available, animal toxicity studies with phenotypic endpoints, and supplemental mechanistic information). The Agency integrated data from these evidence streams to arrive at an overall evidence integration conclusion for each health outcome category (*e.g.,* reproductive toxicity). When weighing and integrating evidence to estimate the potential that HHCB may cause a given human health hazard outcome, EPA uses several factors adapted from Hill (1965). These elements include consistency, dose-response relationship, strength of the association, temporal relationship, biological plausibility, and coherence, among other considerations.

Evidence streams were integrated for non-cancer health outcomes that included acute toxicity (all exposure routes); acute dermal toxicity, subchronic dermal toxicity, dermal irritation, dermal sensitization, eye irritation, liver toxicity, developmental and reproductive toxicity, endocrine disruption (including androgen, estrogen, and thyroid disruption), as well as cancer outcomes.

Because of the relatively small database of human health hazard studies available for HHCB, EPA considered all studies that were put forward for data quality evaluation, including studies for which

DERs were written, when summarizing information for hazard identification, evidence integration, and dose-response analysis. Although certain studies with low or uninformative quality were unsuitable for dose-response analysis, they were still discussed for hazard identification and evidence integration. Additionally, certain supplemental studies that did not receive data quality evaluation scores were also discussed on a case-by-cases basis as appropriate for hazard identification and evidence integration.

6.6 Dermal Absorption

Table 6-3 describes relevant questions to consider when integrating evidence from empirical data, read-across analysis from analog chemicals, and models of dermal absorption.

EPA used an *in vitro* dermal absorption study in human epidermal membranes that pre-dates OECD 428 to estimate parameters applicable for dermal absorption when evaluating risks from HHCB (An-eX, 2001). A DER was written to evaluate the study data quality for this reference, and it received a score of acceptable/non-guideline because it was performed in a manner that was generally consistent with OECD 428. EPA also considered the weight of evidence across two other available dermal absorption studies along with this study. These included an *in vitro* study in a porcine back skin diffusion model (Zhang et al., 2017) and an *in vivo* study of rats and human volunteers (Ford et al., 1999).

For interpretation of the data, EPA applied the relationship of Nderm suggested by (Kissel, 2011) to determine that dermal absorption of HHCB is "flux-limited." Consequently, EPA estimated dermal exposures using a flux-based approach, and the absorptive flux from exposure to liquid materials containing HHCB was estimated using data from (An-eX, 2001). The parameters of surface area and body weight were sourced from the EPA Exposure Factors Handbook (U.S. EPA, 2011), and the absorption time for occupational dermal exposures was sourced from the Chemical Engineering Branch Manual for Preparation of Engineering Assessments (U.S. EPA, 1991).

Table 6-3. Querying the Evidence to Organize Integration for Human Health Dermal Absorption

Evidence Stream (Individual or Combined)	Questions
Studies of Exposed Humans for the Target Chemical	Are there human studies that can be used quantitively to determine dermal absorption estimates or qualitatively in a weight of scientific evidence analysis?
In Vivo Mammalian Animal Studies for the Target Chemical	Are there *in vivo* animal data that can be used quantitatively or qualitatively?
In Vitro/Ex Vivo Studies and Supplemental Information for the Target Chemical	Are there *in vitro* dermal absorption data that can be used quantitatively or qualitatively?
Read Across From Chemical Analogs	Are there human, *in vivo*, or *in vitro/ex vivo* dermal absorption data available for analogs of the target chemical that have similar physical-chemical properties?
Models for K_p and Fraction Absorption	Are there models available to estimate the dermal permeability coefficient (K_p) or fraction absorbed?
Combining Evidence	Are there differences/similarities in dermal absorption across studies? Is there concordance within and across *in vivo* and *in vitro* studies as well as within and across species?

Evidence Stream (Individual or Combined)	Questions
	If read-across analysis from an analog chemical is used, is there consistency with any limited data for the target chemical or among the analog chemical studies? If multiple models are used, is there concordance among the models and with any limited empirical data?

REFERENCES

An-eX. (2001). In-vitro human skin penetration of radiolabelled fragrance material HHCB (redacted). (RIFM/4/00). Woodcliff Lake, NJ: Research Institute for Fragrance Materials Inc.

Api, AM; Belsito, D; Botelho, D; Bruze, M; Burton, GA; Cancellieri, MA; Chon, H; Dagli, ML; Date, M; Dekant, W; Deodhar, C; Fryer, AD; Jones, L; Joshi, K; Kumar, M; Lapczynski, A; Lavelle, M; Lee, I; Liebler, DC; Moustakas, H; Na, M; Penning, TM; Ritacco, G; Romine, J; Sadekar, N; Schultz, TW; Selechnik, D; Siddiqi, F; Sipes, IG; Sullivan, G; Thakkar, Y; Tokura, Y. (2023). RIFM fragrance ingredient safety assessment, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-γ-2-benzopyran, CAS Registry Number 1222-05-5. Food Chem Toxicol 182: 114238. https://dx.doi.org/10.1016/j.fct.2023.114238

CDC. (2022). Formaldehyde (FDH) (CAS RN: 50-00-0): NHANES Biomonitoring Data (Blood; Cigarette smoke). Atlanta, GA: Centers for Disease Control and Prevention. Retrieved from https://www.cdc.gov/exposurereport/data_tables.html?NER_SectionItem=NHANES

Chase Products. (2025). Safety Data Sheet (SDS) Group: Champion Sprayon Spray Scents Metered Air Freshener/Deodorizer (Odor Neutralizer, Warm Harvest, Cucumber Melon, Exotic Garden, Hawaiian Island). Broadview, IL. https://www.chaseproducts.com/products.cfm?cat=Cleaners_and_Disinfectants&cat1=Air_Fresheners&cat2=Metered_Air_Fresheners

Dodson, RE; Bessonneau, V; Udesky, JO; Nishioka, M; McCauley, M; Rudel, RA. (2019). Passive indoor air sampling for consumer product chemicals: A field evaluation study. J Expo Sci Environ Epidemiol 29: 95-108. https://dx.doi.org/10.1038/s41370-018-0070-9

Dodson, RE; Udesky, JO; Colton, MD; Mccauley, M; Camann, DE; Yau, AY; Adamkiewicz, G; Rudel, RA. (2017). Chemical exposures in recently renovated low-income housing: Influence of building materials and occupant activities. Environ Int 109: 114-127. https://dx.doi.org/10.1016/j.envint.2017.07.007

Ehiguese, FO; Rodgers, ML; Araújo, CVM; Griffitt, RJ; Martin-Diaz, ML. (2021). Galaxolide and tonalide modulate neuroendocrine activity in marine species from two taxonomic groups. Environ Res 196: 110960. https://www.sciencedirect.com/science/article/pii/S0013935121002541?via%3Dihub

Fasano, WJ; Manning, LA; Green, JW. (2002). Rapid integrity assessment of rat and human epidermal membranes for in vitro dermal regulatory testing: correlation of electrical resistance with tritiated water permeability. Toxicol In Vitro 16: 731-740. https://www.sciencedirect.com/science/article/pii/S088723330200084X?via%3Dihub

FCA. (2021). Site emission survey of fragrance formulation compounders and product manufacturers using HHCB: Information to support the TSCA risk evaluation; with comment, dated 08/05/2021. (EPA-HQ-OPPT-2018-0430-0043). Arlington, VA. https://www.regulations.gov/comment/EPA-HQ-OPPT-2018-0430-0043

Fontal, M; van Drooge, BL; Grimalt, JO. (2016). A rapid method for the analysis of methyl dihydrojasmonate and galaxolide in indoor and outdoor air particulate matter. J Chromatogr A 1447: 135-140. https://dx.doi.org/10.1016/j.chroma.2016.04.028

Ford, RA; Hawkins, DR; Schwarzenbach, R; Api, AM. (1999). The systemic exposure to the polycyclic musks, AHTN and HHCB, under conditions of use as fragrance ingredients: Evidence of lack of complete absorption from a skin reservoir. Toxicol Lett 111: 133-142. https://dx.doi.org/10.1016/S0378-4274(99)00174-5

Hill, AB. (1965). The environment and disease: Association or causation? Proc R Soc Med 58: 295-300. https://journals.sagepub.com/doi/10.1177/003591576505800503

Kissel, JC. (2011). The mismeasure of dermal absorption. J Expo Sci Environ Epidemiol 21: 302-309. https://dx.doi.org/10.1038/jes.2010.22

NTP. (2015). OHAT risk of bias rating tool for human and animal studies. U.S. Dept. of Health and

Human Services, National Toxicology Program. https://ntp.niehs.nih.gov/ntp/ohat/pubs/riskofbiastool_508.pdf

NTP. (2019). Handbook for conducting a literature-based health assessment using OHAT approach for systematic review and evidence integration. Research Triangle, NC: National Institute of Environmental Health Sciences. https://ntp.niehs.nih.gov/ntp/ohat/pubs/handbookmarch2019_508.pdf

OECD. (2004a). Guidance document for the conduct of skin absorption studies. (ENV/JM/MONO(2004)2). https://www.oecd-ilibrary.org/environment/guidance-document-for-the-conduct-of-skin-absorption-studies_9789264078796-en;jsessionid=R95G2RBh7UhKBExKA28kPPHPPmxc8LYbY3f6KXt8.ip-10-240-5-151

OECD. (2004b). Test No. 427: Skin absorption: in vivo method. Paris, France.

OECD. (2004c). Test No. 428: Skin absorption: In vitro method. Paris, France. https://dx.doi.org/10.1787/9789264071087-en

OECD. (2011). Guidance notes on dermal absorption. (ENV/JM/MONO(2011)36). https://www.oecd.org/env/ehs/testing/48532204.pdf

OECD. (2022). Series on Testing & Assessment, No. 156: Guidance notes on dermal absorption studies (Second edition). (ENV/JM/MONO(2011)36/REV1). Paris, France: Organisation for Economic Co-operation and Development (OECD). https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-JM-MONO(2011)36%20&doclanguage=en

QuanTech. (2021). American Healthy Homes Survey, final report: Data documentation. (AHHSII). Washington, DC: U.S. Department of Housing and Urban Development. https://www.hud.gov/program_offices/healthy_homes

Reiner, JL; Wong, CM; Arcaro, KF; Kannan, K. (2007). Synthetic musk fragrances in human milk from the United States. Environ Sci Technol 41: 3815-3820. https://dx.doi.org/10.1021/es063088a

Shapiro, AJ; Antoni, S; Guyton, KZ; Lunn, RM; Loomis, D; Rusyn, I; Jahnke, GD; Schwingl, PJ; Mehta, SS; Addington, J; Guha, N. (2018). Software tools to facilitate systematic review used for cancer hazard identification. Environ Health Perspect 126: 104501.

U.S. EPA. (1991). Chemical engineering branch manual for the preparation of engineering assessments. (68-D8-0112). Cincinnati, OH: US Environmental Protection Agency, Office of Toxic Substances. https://nepis.epa.gov/Exe/ZyPDF.cgi/P10000VS.PDF?Dockey=P10000VS.PDF

U.S. EPA. (2011). Exposure factors handbook: 2011 edition [EPA Report]. (EPA/600/R-090/052F). Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100F2OS.txt

U.S. EPA. (2016). Chemical data reporting: 2016 data. Washington, DC: U.S. Environmental Protection Agency, Chemical Data Reporting. Retrieved from https://www.epa.gov/chemical-data-reporting/access-cdr-data#2016

U.S. EPA. (2017). Update for Chapter 5 of the Exposure Factors Handbook: Soil and dust ingestion [EPA Report]. (EPA/600R-17/384F). Washington, DC: National Center for Environmental Assessment, Office of Research and Development. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100TTX4.txt

U.S. EPA. (2018). Application of systematic review in TSCA risk evaluations. (740-P1-8001). Washington, DC: U.S. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention. https://www.epa.gov/sites/production/files/2018-06/documents/final_application_of_sr_in_tsca_05-31-18.pdf

U.S. EPA. (2019). Point Source Calculator: A Model for Estimating Chemical Concentration in Water Bodies. Washington, DC: U.S. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention.

U.S. EPA. (2020). 2020 CDR data [Database]. Washington, DC: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. Retrieved from https://www.epa.gov/chemical-data-reporting/access-cdr-data

U.S. EPA. (2021). Draft systematic review protocol supporting TSCA risk evaluations for chemical substances, Version 1.0: A generic TSCA systematic review protocol with chemical-specific methodologies. (EPA Document #EPA-D-20-031). Washington, DC: Office of Chemical Safety and Pollution Prevention. https://www.regulations.gov/document/EPA-HQ-OPPT-2021-0414-0005

U.S. EPA. (2022a). Ambient Monitoring Technology Information Center (AMTIC) - Ambient Monitoring Archive for HAPs [Database]. Washington, DC. Retrieved from https://www.epa.gov/amtic/amtic-ambient-monitoring-archive-haps

U.S. EPA. (2022b). Final scope of the risk evaluation for octamethylcyclotetrasiloxane (Cyclotetrasiloxane, 2,2,4,4,6,6,8,8-octamethyl-) (D4); CASRN 556-67-2. (EPA 740-R-21-003). Washington, DC: Office of Chemical Safety and Pollution Prevention. https://www.epa.gov/system/files/documents/2022-03/casrn_556_67_2-octamethylcyclotetra-siloxane-d4_finalscope.pdf

U.S. EPA. (2024). Toxics Release Inventory (TRI) data: 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-g-2- benzopyran (HHCB), reporting year 2023 [Database]. Washington, DC. Retrieved from https://www.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-present

U.S. EPA. (2025). Masterlist: HHCB Product Concentration Data. Washington, DC.

U.S. EPA. (2026a). Draft Data Evaluation Records for Human Health Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026b). Draft Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026c). Draft Data Quality Evaluation and Data Extraction Information for Dermal Absorption for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026d). Draft Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026e). Draft Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026f). Draft Data Quality Evaluation Information for Environmental Hazard for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026g). Draft Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026h). Draft Data Quality Evaluation Information for Human Health Hazard Animal Toxicology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2026i). Draft Data Quality Evaluation Information for Human Health Hazard Epidemiology for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB).

Washington, DC: Office of Pollution Prevention and Toxics.
U.S. EPA. (2026j). Draft Environmental Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.
U.S. EPA. (2026k). Draft Human Exposure Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.
U.S. EPA. (2026l). Draft Human Health and Environmental Hazard Assessment for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.
U.S. EPA. (2026m). Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB). Washington, DC: Office of Pollution Prevention and Toxics.
U.S. EPA; USGS; NWQMC. (2022). Formaldehyde (FDH) (CAS RN: 50-00-0): WQP Output (NWIS, STEWARDS & STORET), Site data & sample results (physical/chemical metadata) [Database]: National Water Quality Monitoring Council. Retrieved from https://acwi.gov/monitoring/waterqualitydata.html
Zhang, X; Yu, Y; Gu, Y; Li, X; Zhang, X; Yu, Y. (2017). In vitro determination of transdermal permeation of synthetic musks and estimated dermal uptake through usage of personal care products. Chemosphere 173: 417-424. https://dx.doi.org/10.1016/j.chemosphere.2017.01.001