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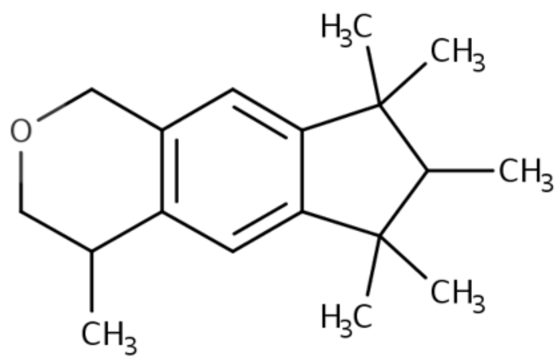
United States
Environmental Protection Agency

Office of Chemical Safety and
Pollution Prevention

# Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)

## CASRN 1222-05-5



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**Docket**

Supporting information can be found in the public docket, EPA-HQ-OPPT-2018-0430.

**Disclaimer**



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# EXECUTIVE SUMMARY

***Background***

HHCB (1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran) was evaluated under section 6 of the Toxic Substances Control Act (TSCA). In this draft risk evaluation, HHCB is preliminarily determined not to present an unreasonable risk of injury to human health or the environment across the identified conditions of use (COUs), ranging from manufacture to disposal. No COUs for HHCB are found to significantly contribute to unreasonable risk for workers, consumers, and the general population, including subsistence fishers and tribal populations.

In December 2019, HHCB was designated as a high-priority chemical substance for TSCA risk evaluation, and in August 2020 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 1222-05-5* (U.S. EPA, 2020c) was released. HHCB is a synthetic musk fragrance used in household products such as detergents, cleaners, and air fresheners. It is also used in perfumes, cosmetics, and personal care products not regulated under TSCA. Manufacturers report HHCB production volumes under the Chemical Data Reporting rule (CDR; CASRN 1222-05-5). Reported national aggregate volume has remained at 1 to 10 million pounds (lb) from 2012 to 2020 (U.S. EPA, 2020b). Preliminary 2024 CDR data indicate 2020 to 2023 volumes are expected to be similar to those reported in previous CDR cycles.

This draft risk evaluation assesses human health risk to workers, consumers, and the general population, including subsistence fishers and tribal populations. It also assesses environmental risks. Workers may be exposed to HHCB via dust, mist, or vapor during manufacture or use (Section 3.3.1) whereas consumers may be similarly exposed during typical product use (*e.g.,* cleaning, using bathroom air fresheners, laundering). Although manufacturing can release HHCB to water, most environmental loadings arise from down-the-drain disposal following commercial and consumer use (Sections 1.4.2 and Section 1.4.3.1).

All reasonably available information was evaluated for occupational (Section 3.3.1), consumer (Section 3.3.2), and general population exposure (Section 3.3.3)—including potentially exposed and susceptible subpopulations (PESS; see Section 3.4.5). Potential routes include inhalation (vapor, mist, or dust), oral ingestion (drinking water, human milk, fish, or soil), and dermal contact. A tiered approach prioritized COUs with the highest expected exposure for a population group (Section 3.2). Occupational non-users, who do not directly handle HHCB but may be indirectly exposed to the substance in their workspace, were not estimated separately as their exposures are expected to be similar to or lower than direct-user exposures.

The following three TSCA-based aggregate exposure scenarios were selected to represent the highest potential long-term exposures to HHCB (Section 3.3.5):

- **Aggregate Exposure Scenario 1 (Worker + Drinking Water + Fish Ingestion [Adults, 21+ Years]):** Workplace inhalation (HHCB dust during compounding/converting) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 2.3).
- **Aggregate Exposure Scenario 2 (Consumer + Drinking Water + Fish Ingestion [Adults, 21+ Years]):** Consumer inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 2.3).
- **Aggregate Exposure Scenario 3 (Consumer [Infants, <1 Year] + Drinking Water):** Consumer (infants, <1 year) inhalation from continuous action air fresheners at home combined

with oral ingestion from HHCB in drinking water.

HHCB is released to the environment via surface water discharges, land disposal, and air emissions from industrial and commercial facilities. Releases to surface waters are primarily from down-the-drain disposal following commercial and consumer use. In surface waters, HHCB partitions to sediment, reducing water column exposures while increasing exposure for sediment-dwelling or sediment-consuming organisms.

Environmental concentrations were estimated for (1) industrial, commercial consumer, and commercial plus consumer releases to surface water and sediment (Section 1.4.2); (2) biosolid land application to soil (Section 1.4.3.2); and (3) bioconcentration in aquatic organisms (Section 1.4.3.1). Expected exposure pathways include surface water and sediment downstream of wastewater treatment facility discharges and soil following biosolid application (Section 1.4.3). Air exposures were considered but not assessed due to rapid degradation of HHCB in air (Sections 1.3.2).

A tiered approach was applied, combining screening-level methods with more refined analyses tailored to the evaluated population and exposure pathways. Upper-bound environmental exposure concentrations were estimated for industrial and down-the-drain releases of HHCB to surface water, sediment, and fish tissues. Land pathway exposures were assessed using measured soil concentrations.

Given the wide variability in empirical fish bioaccumulation indices and the uncertainties in the relative importance of gill versus dietary uptake in fish, the screening-level, bioaccumulation assessment was refined using a two-compartment kinetic mass-balance model (ADME-B; (Gobas et al., 2019)) and a food web bioaccumulation model (KABAM; ($K_{OW}$ [based] Aquatic BioAccumulation Model) (U.S. EPA, 2009)). KABAM results provide an additional line of evidence and increase confidence that the fish HHCB concentrations reported are conservative, protective upper bounds on dietary exposures.

Overall, the weight of evidence—including measured fish concentrations, screening level fish concentration estimates, and KABAM outputs—supports robust confidence that the exposure concentrations used are upper bound values suitable for use in a screening-level risk assessment.

Prior assessments completed by the European Chemicals Bureau (ECB) (2008a, b) and by EPA (2014) did not include a recent OECD (Organisation for Economic Co-operation and Development) 443 extended one-generation reproductive toxicity (EOGRT) study that was identified through EPA's systematic review. The non-cancer point of departure (POD) selected for intermediate and chronic exposure is based on decreased offspring body weight in rats from the EOGRT study (IFF, 2021). It is considered health-protective, including for PESS. EPA considered acute oral, inhalation, and dermal studies, as well as recent EOGRT and developmental toxicity data, and identified no effects suitable for deriving an acute (Section 3.1) health hazard for any route of exposure. EPA also did not derive a dermal hazard value for HHCB based on the weight of evidence from studies on dermal absorption, acute and subchronic systemic dermal toxicity, dermal irritation, and dermal sensitization. Finally, using the ReCAAP (Rethinking Chronic Toxicity and Carcinogenicity Assessment for Agrochemicals Project) weight of evidence framework (Hilton et al., 2022), EPA determined that the absence of cancer bioassays for HHCB does not impart scientific uncertainty in the risk characterization. The non-cancer POD is protective of human health, including for potential cancer effects. Therefore, EPA did not derive a separate cancer hazard value (Section 3.1.2) for HHCB.

Previous government/regulatory assessments reached conclusions similar to this draft risk evaluation. The 2014 TSCA Work Plan assessment noted HHCB's initial selection was due to moderate developmental toxicity concern and high exposure potential. Ultimately, EPA concluded the overall human health hazard concern, including developmental toxicity, was low (OCSPP, 2014; ECB, 2008a, b). The European Union determined no further information/testing or additional risk-reduction measures were needed for consumers, workers, or the general population (ECB, 2008a, b). The Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS) likewise found no critical health effects and concluded risks to public health and workers were not unreasonable (NICNAS, 2019).

The 2014 TSCA Work Plan assessment reported low concern for aquatic and sediment organisms, with exposures one to two orders of magnitude below previously identified hazard threshold concentrations (OCSPP, 2014). Similarly, the ECB Risk Assessment Report found all aquatic/sediment scenarios had Predicted Environmental Concentration/Predicted No-Effect Concentration ratios less than 1, indicating no need for further information/testing or additional measures (ECB, 2008b).

This draft risk evaluation addresses risks from HHCB under the COUs subject to TSCA (industrial and commercial manufacture, processing, distribution, use, disposal) and related consumer product uses. Human and environmental exposure to HHCB through uses that are not subject to TSCA (*e.g.,* cosmetics, medical devices, food additives) were not evaluated as they are excluded from the definition of a chemical substance under TSCA section 3(2)(B). Accordingly, the conclusions in this draft risk evaluation cannot be extrapolated to form conclusions about uses of HHCB that are not subject to TSCA and that the Agency did not evaluate.

***Determining Unreasonable Risk to Human Health***

In TSCA existing chemical risk evaluations, EPA must determine whether a chemical substance presents unreasonable risk of injury to human health or the environment under the COUs. The Agency must use the best available science in making this determination. In determining whether HHCB presents unreasonable risk to human health, the Agency considers risk-related factors as described in its risk evaluation framework rule (U.S. EPA, 2024b) 89 Fed. Reg. 37028, 37037 (May 3, 2024). Risk-related factors beyond consideration of benchmark levels of HHCB that EPA has identified include the following: the type of health effect under consideration; the reversibility of the health effect being evaluated; exposure-related considerations (*e.g.,* duration, magnitude, frequency of exposure); population exposed (including any potentially exposed or susceptible subpopulations), and EPA's confidence in the information used to inform the hazard and exposure values. These considerations inform the evaluation of hazard and exposure to HHCB. If an estimate of risk for a specific COU indicates risk (*e.g.,* margin of exposure below the benchmark for non-cancer health effects) then the formal determination of whether those risks significantly contribute to unreasonable risk under TSCA is both case-by-case and context-driven. EPA considers all the aforementioned risk-related factors when making a determination of whether a COU significantly contributes to unreasonable risk.

The Agency evaluated the risks to workers, consumers, and the general population from HHCB exposure. In its human health evaluation, the Agency used a screening approach to assess how people might be exposed to HHCB through inhalation exposures to workers and consumers and through ingestion exposures to the general population. In determining whether HHCB presents an unreasonable risk of injury to human health, EPA considered the following PESS in its assessment: women of reproductive age; pregnant women, infants, children and adolescents; people who frequently use consumer products and/or articles containing high-concentrations of HHCB; people exposed to HHCB in the workplace; people who may be in proximity to releasing facilities; and people whose diets include large amounts of fish (*i.e.,* subsistence fisher and tribal populations). These subpopulations are PESS because some have greater exposure to HHCB per body weight (*e.g.,* infants, children, adolescents) while others may experience exposure from multiple sources or experience higher exposures than others.

***Determining Unreasonable Risk to the Environment***

EPA estimated and predicted environmental concentrations of HHCB from industrial and down-the-drain releases from commercial and consumer uses into surface water and sediment, biosolid applications to soil, and bioconcentration in aquatic animals to terrestrial organisms. The Agency expects HHCB environmental exposure pathways in surface water and sediment after discharge from wastewater treatment facilities and in soil after application of biosolids. EPA characterized the environmental risk of HHCB using risk quotients, which compare the predicted environmental concentration with hazard threshold values. In determining whether HHCB presents an unreasonable risk of injury to the environment, EPA considered the following groups of organisms in its assessment: aquatic vertebrates, aquatic invertebrates, terrestrial plants, soil invertebrates, and mammals.

***Summary and Considerations***

EPA has preliminarily determined that HHCB does not present an unreasonable risk of injury to human health or the environment. This preliminary determination is based on the information in this draft risk evaluation, the appendices, technical support documents (TSDs), and supplemental files (see Appendix C) in accordance with TSCA section 6(b).

EPA has preliminarily determined that HHCB does not present unreasonable risk to human health or the environment under all (22) COUs evaluated:

- Manufacturing – Domestic manufacture
- Manufacturing – Import
- Processing – Incorporation into formulation, mixture, or reaction product – Odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials
- Processing – Incorporation into articles – Odor agent in plastics material and resin manufacturing
- Processing – Repackaging – Odor agent in all other chemical product and preparation manufacturing
- Processing – Recycling
- Distribution in commerce
- Commercial use – Air care products – Air fresheners for motor vehicles
- Commercial use – Air care products – Continuous action air fresheners
- Commercial use – Air care products – Instant action air fresheners
- Commercial use – Cleaning and furnishing care products – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)
- Commercial use – Laundry and dishwashing products – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash)
- Commercial use – Plastic and rubber articles not covered elsewhere – Plastic and rubber articles
- Commercial use – Other use laboratory chemicals – Laboratory chemicals
- Consumer use – Air care products – Air fresheners for motor vehicles
- Consumer use – Air care products – Continuous action air fresheners
- Consumer use – Air care products – Instant action air fresheners
- Consumer use – Cleaning and furnishing care products – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes;

Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)

- Consumer use – Laundry and dishwashing products – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/ granule); Dishwashing detergent liquid (hand-wash)
- Consumer use – Plastic and rubber articles not covered elsewhere – Plastic and rubber articles
- Consumer use – Chemical substances in treatment products – Ion exchangers; Liquid water treatment products; Solid powder water treatment products
- Disposal

***Next Steps and Public Input***

This draft risk evaluation and accompanying TSDs and supplemental files have been released for public comment and external peer review. EPA seeks public comment on all aspects of this draft risk evaluation for HHCB; in particular, the Agency seeks comment on the following:

- product-specific HHCB concentration ranges and use patterns (*e.g.,* air care, cleaning, laundry/dishwashing, plastics/rubber, water treatment chemicals);
- workplace exposure information (air monitoring data, engineering controls, and personal protective equipment [PPE] practices) for manufacturing, compounding/converting, and repackaging;
- down-the-drain release estimates; wastewater treatment removal efficiencies; wastewater treatment plant influent/effluent, biosolids, and receiving-water/sediment monitoring; and fish tissue data;
- information relevant to PESS (*e.g.,* infants, children, subsistence fishers, tribal communities), including high-end use patterns and exposure measurements;
- selection and characterization of the bioaccumulation value, implementation of additional modeling refinements, and resulting conclusions; and
- use of screening-level exposure approaches for occupational and consumer assessments.

The Agency also seeks comment on the following weight of evidence conclusions from the human health hazard assessment:

- HHCB is not acutely hazardous for any route of exposure and rationale to not derive hazard values or estimate risks for this exposure duration;
- HHCB is not hazardous via the dermal route and rationale to not derive hazard values or estimate risks for this exposure route; and
- The lack of chronic toxicity and carcinogenicity bioassays for HHCB does not suggest that there are significant remaining scientific uncertainties in the qualitative and quantitative risk characterization for this chemical.

The independent Science Advisory Committee on Chemicals (SACC; accessed March 11, 2026) will peer review the draft risk evaluation and TSDs for HHCB during its June 2026 meeting. Recommendations from the SACC as well as public comments will be used to inform the final risk evaluation for HHCB.

# 1 INTRODUCTION

1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB, CASRN 1222-05-5) is being evaluated under the Toxic Substances Control Act (TSCA) section 6(b). 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 1222-05-5* (also called the "final scope document") (U.S. EPA, 2020c) was published in August 2020. More information on the TSCA existing chemical risk evaluation process, including the components and associated timeline, is provided on the TSCA website.[1]

## 1.1 Scope and Organization of the Risk Evaluation

This *Draft Risk Evaluation for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (also called "Draft Risk Evaluation for HHCB") Environmental Exposure Assessment comprises a series of technical support documents (TSDs). Each TSD contains sub-assessments that inform adjacent, "downstream" TSDs. A basic diagram of the HHCB risk evaluation and related assessments/documents is provided in Figure 1-1.

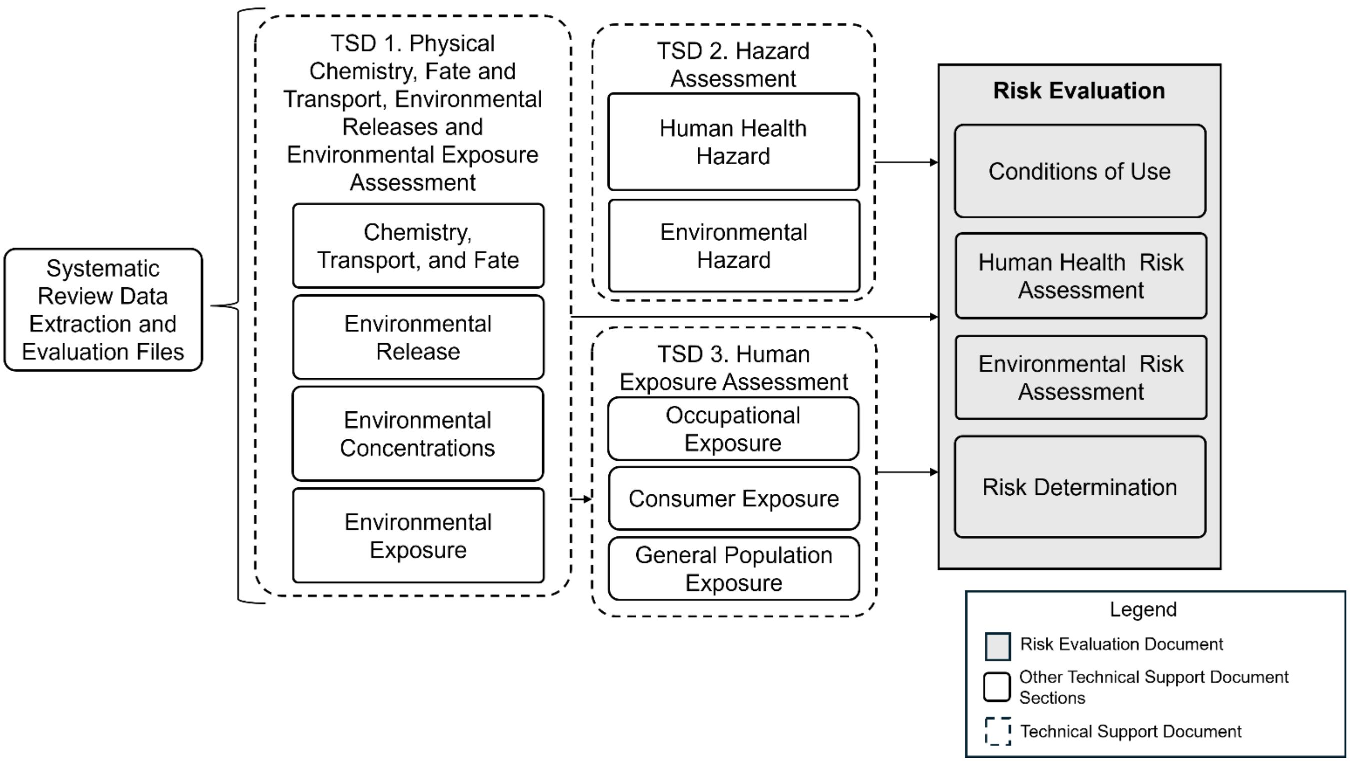


**Figure 1-1. Draft Risk Evaluation Document Map for HHCB**

The TSDs draw on data and information sources identified in the final scope document (U.S. EPA, 2020c). A comprehensive search for reasonably available information was conducted to identify HHCB data for the risk evaluation, consistent with TSCA requirements. Discipline-specific approaches for identifying relevant risk assessment information are detailed in the *Draft Systematic Review Protocol for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026af) (also called the "Draft Systematic Review for HHCB"), and where applicable, within each TSD. Documentation of source data, evaluations, extractions, and other information is provided in the supplemental documents and spreadsheets (files) listed in Appendix C. This draft risk evaluation focuses

[1] https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-evaluations-existing-chemicals-under-tsca (accessed March 11, 2026)

on the risk characterization for HHCB and includes high-level summaries of each TSD (detailed information is available in the corresponding documents) and presents environmental and human health risk characterizations as follows:

- Section 1.3 summarizes basic physical and chemical properties as well as the transport and fate characteristics of HHCB.
- Section 1.4 summarizes releases to the environment and concentrations of HHCB in the environment.
- Section 2 presents the environmental risk assessment, including a summary of environmental concentrations and exposures (Section 2.3), a summary of environmental hazards (Section 2.1), and risk estimates for environmental receptors (Section 2.4).
- Section 3 presents the human health risk assessment, including a summary of human exposure assessments for occupational, consumer, and general population exposure (Section 3.3); a summary of human health hazards (Section 3.1); and a summary of risk estimates for human health (Section 3.4).
- Section 4 presents the preliminary unreasonable risk determination for human health or the environment. are found to significantly contribute to unreasonable risk.

This draft risk evaluation also includes seven appendices (A through G).

### 1.1.1 Life Cycle and Production Volume

The life cycle diagram (LCD) in Figure 1-2 below depicts the HHCB COUs considered in this draft risk evaluation across key life cycle stages: manufacturing, processing, distribution, use (commercial and consumer), and disposal. The LCD has been updated from the final scope document (U.S. EPA, 2020c) to reflect the latest HHCB use information. Content is organized using Chemical Data Reporting (CDR) rule processing codes and use categories, including functional-use codes for industrial uses and product categories for commercial and consumer uses.

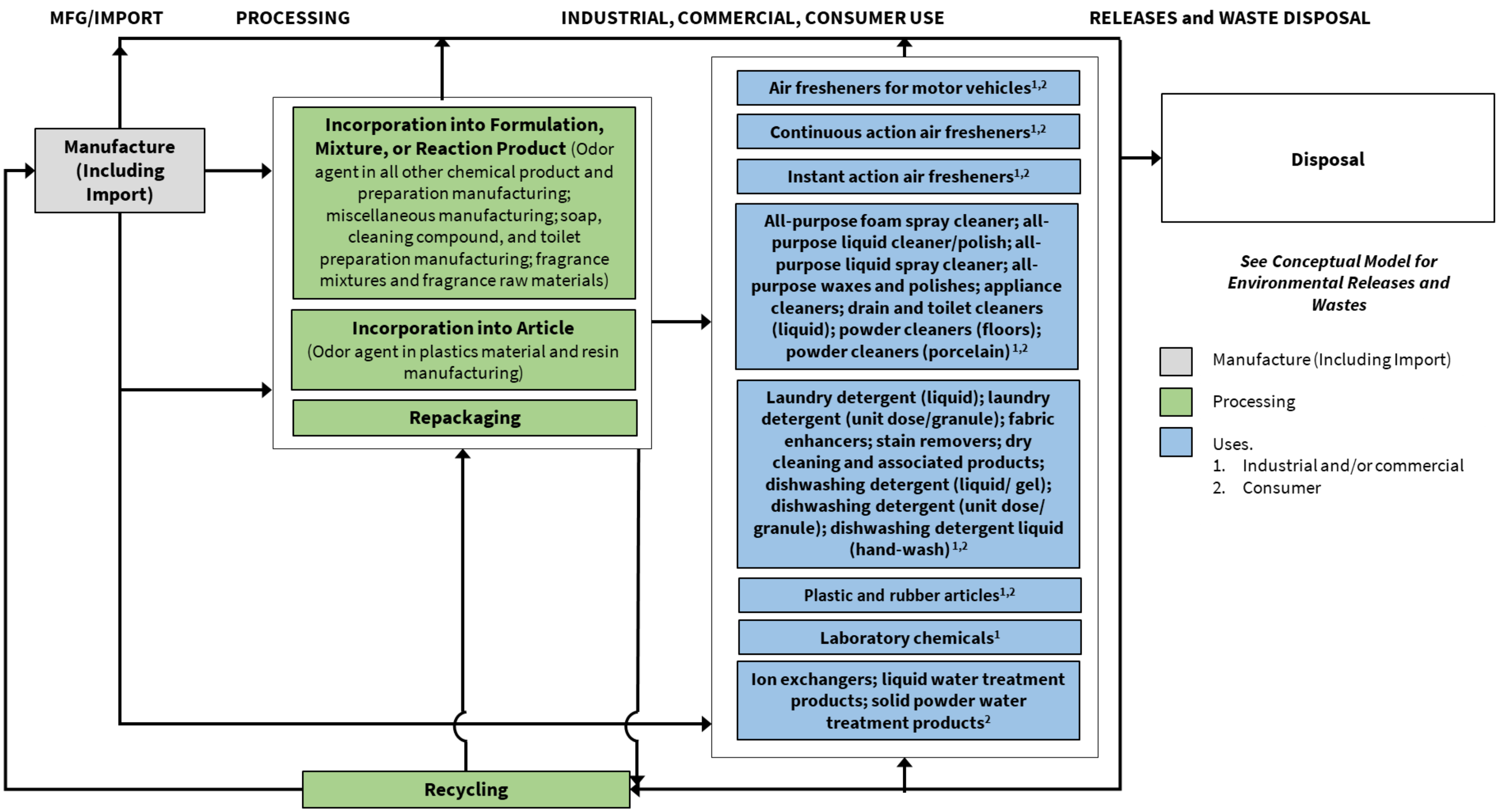


**Figure 1-2. HHCB Life Cycle Diagram**

[a] See Table 1-1 for categories and subcategories of COUs.

Under TSCA section 8(a) (see 40 CFR part 711), the CDR ruke requires U.S. manufacturers and importers to report information to EPA on chemicals manufactured or imported. CDR data are collected approximately every 4 years; the most recent collection was in 2024. HHCB production volume remained in the 1,000,000 to 10,000,000 pounds (lb) aggregate range from 2012 to 2020 (U.S. EPA (2020b). Preliminary 2024 CDR data indicate 2020 to 2023 production volume is expected to be similar to the previous CDR cycles. This document provides brief summaries of use category; more detailed descriptions (*e.g.,* process descriptions, worker activities, process flow diagrams, equipment illustrations) are provided 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)* (also called the "Draft HHCB Human Exposure Assessment" TSD) (U.S. EPA, 2026s).

## 1.2 Conditions of Use Included in the Risk Evaluation

The final scope document for HHCB (U.S. EPA, 2020c) identified and described the life cycle stages, categories, and subcategories comprising the COUs under TSCA considered in this draft risk evaluation. Under TSCA Section 3(4), COUs are "the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of." COUs are identified during scoping and may be refined between the scope document and the risk evaluation as additional information is gathered. For clarity, descriptions of each COU under evaluation are presented in Appendix D.1.

As part of the draft risk evaluation for HHCB, the COUs identified in the 2020 final scope (U.S. EPA, 2020c) were revised and updated. All COUs considered in this draft are shown in the LCD (Figure 1-2) and conceptual models (see Section 2.2). For clarity, Appendix D.1 provides COU descriptions, including updates with explanations for the updates. These revisions reflect improved understanding based on stakeholder outreach, public comments, and updated CDR information—including new 2020 submissions and changes to processing, industrial, consumer, and commercial product category names. Table 1-1 presents the COUs evaluated in this draft risk evaluation for HHCB.

**Table 1-1. Categories and Subcategories of Use Included in the Risk Evaluation for HHCB**

| Life Cycle Stage[a] | Category[b] | Subcategory[c] | Reference(s) |
|---|---|---|---|
| Manufacturing | Manufacture – Domestic manufacture | Domestic manufacturing | U.S. EPA (2019b) |
| Manufacturing | Manufacture – Import | Importing | U.S. EPA (2019b) |
| Processing | Incorporation into formulation, mixture or reaction product | Odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials | U.S. EPA (2019b) |
| Processing | Incorporation into articles | Odor agent in plastics material and resin manufacturing | U.S. EPA (2019b) |
| Processing | Repackaging | Odor agent in all other chemical product and preparation manufacturing | U.S. EPA (2019b) |
| Processing | Recycling | Recycling | U.S. EPA (2019b) |
| Distribution in commerce | Distribution in commerce | Distribution in commerce | |
| Commercial use | Air care products | Air fresheners for motor vehicles | U.S. EPA (2019b) |

| Life Cycle Stage[a] | Category[b] | Subcategory[c] | Reference(s) |
|---|---|---|---|
| Commercial use | Air care products | Continuous action air fresheners | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0012 |
| Commercial use | Air care products | Instant action air fresheners | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0012 |
| Commercial use | Cleaning and furnishing care products | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) | U.S. EPA (2019b) |
| Commercial use | Laundry and dishwashing products | Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash) | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0013 |
| Commercial use | Plastic and rubber articles not covered elsewhere | Plastic and rubber articles | U.S. EPA (2019b) |
| Commercial use | Other use laboratory chemicals | Laboratory chemicals | Sigma-Aldrich (2019) |
| Consumer use | Air care products | Air fresheners for motor vehicles | U.S. EPA (2019b) |
| Consumer use | Air care products | Continuous action air fresheners | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0012 |
| Consumer use | Air care products | Instant action air fresheners | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0012 |
| Consumer use | Cleaning and furnishing care products | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) | U.S. EPA (2019b) |
| Consumer use | Laundry and dishwashing products | Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash) | U.S. EPA (2019b); EPA-HQ-OPPT-2018-0430-0013 |

| Life Cycle Stage[a] | Category[b] | Subcategory[c] | Reference(s) |
|---|---|---|---|
| Consumer use | Plastic and rubber products not covered elsewhere | Plastic and rubber articles | U.S. EPA (2019b) |
| Consumer use | Chemical substances in treatment products | Ion exchangers; Liquid water treatment products; Solid powder water treatment products | (U.S. EPA, 2020a) |
| Disposal | Disposal | Disposal | U.S. EPA (2019b) |

[a] Life Cycle Stage Use Definitions (40 CFR 711.3)

- "Industrial use" means use at a site at which 1 or more chemicals or mixtures are manufactured (including imported) or processed.
- "Commercial use" means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services.
- "Consumer use" means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use.
- Although EPA has identified both industrial and commercial uses here for purposes of distinguishing scenarios in this document, the Agency interprets the authority over "any manner or method of commercial use" under TSCA section 6(a)(5) to reach both.

[b] These categories of conditions of use (COUs) appear in the life cycle diagram (LCD), reflect CDR codes, and broadly represent COUs of DBP in industrial and/or commercial settings.

[c] These subcategories represent more specific activities within the life cycle stage and category of the COUs of HHCB.

## 1.3 Chemistry, Transport, and Fate

### 1.3.1 Summary of Physical and Chemical Properties

HHCB is a colorless viscous liquid with a strong musk odor at room temperature. As noted in 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 called the "Draft HHCB Environmental Exposure Assessment" TSD) (U.S. EPA, 2026s), it is sometimes referred to as Galaxolide. HHCB consists of four diastereomers (*i.e.,* an isomer that differs in the spatial arrangement of atoms in the molecule but is not a mirror image). Two (-)/4S isomers (4S, 7R & 4S, 7S) have the characteristic odor, and the other two (+)/4R isomers (4R, 7R & 4R, 7S) have little to no odor. In addition, Galaxolide is often combined with diethyl phthalate (DEP) to enhance fragrance longevity and serve as a fixative. The mixture of isomers or combination with DEP can affect some physical and chemical properties as well as the toxicity profile. Information for every endpoint on whether it is a mixture or a neat compound is not available (U.S. EPA, 2026s).

Table 1-2 provides the selected physical and chemical properties. Water solubility (1.75 mg/L) and log $K_{OW}$ (5.9) indicate the chemical substance is lipophilic. The chemical also has low volatility as indicated by its vapor pressure ($5.45\times10^{-5}$ mm Hg).

**Table 1-2. Physical and Chemical Properties of HHCB**

| Property | Value[a b] | Reference | Data Quality Rating |
|---|---|---|---|
| Molecular formula | $C_{18}H_{26}O$ | N/A | N/A |
| Molecular weight | 258.41 g/mol | N/A | N/A |
| Physical state | Viscous liquid | NLM (2018) | High |
| Physical properties | Colorless, strong musk odor | NLM (2018) | High |
| Vapor pressure | $5.45\times10^{-4}$ mm Hg at 25 °C | MacGillivray (1996) | High |
| | $1.99\times10^{-3}$ mm Hg at 47 °C | Wootitunthipong and Chickos (2019) | High |
| Water solubility | 1.75 mg/L at 25 °C | Edwards (1996) | High |
| Octanol/water partition coefficient (log $K_{OW}$) | 5.9 (unitless) | U.S. EPA (2019c) | High |
| Henry's Law constant | $1.06\times10^{-4}$ atm·m$^3$/mole at 25 °C | U.S. EPA (2012) | High |
| Viscosity | 12,914 centipoise (cP) | NLM (2018) | High |
| Refractive index | 1.5342 | O'Neil et al. (2013) | High |

[a] Measured unless otherwise noted.
[b] The composition of tested substance is not always provided in the study and can result in wide variation of the reported value.

### 1.3.2 Summary of Environmental Transport and Fate

HHCB is persistent in some environmental media compartments, including surface water, sediments, and soils amended with biosolids. HHCB is semi-volatile and can be present in air at trace concentrations but has a short half-life of 3.7 hours (U.S. EPA, 2008). Table 1-3 provides all selected environmental transport and fate characteristics for this draft risk evaluation.

**Table 1-3. Environmental Transport and Fate Characteristics of HHCB**

| Property or Endpoint | Value[a] | Reference | Data Quality Rating |
|---|---|---|---|
| Direct photodegradation | Half-life ($t_{1/2}$) = 3.7 hours | U.S. EPA (2008) | Medium |
| Indirect photodegradation | Half-life ($t_{1/2}$) = 10.9 hours based on ·OH reaction rate constant of $2.71\times10^{-11}$ cm$^3$/molecules·second | Li et al. (2018) | High |
| Hydrolysis | Stable; HHCB is not expected hydrolyze in the environment because its structure lacks hydrolytically labile functional groups | NLM (2018); OECD (2009) | Not Rated |
| Biodegradation | Stable; 0% / 28 days $CO_2$ evolution test (OECD test guideline 301 B) (aerobic water) | (U.S. EPA, 2008) | High |
| Field degradation | Half-life ($t_{1/2}$) = 140–144 days in biosolid-amended soils | (DiFrancesco et al., 2004) | High |

| Property or Endpoint | Value[a] | Reference | Data Quality Rating |
|---|---|---|---|
| Removal in wastewater treatment | 92% total removal (0.8% by biodegradation, 91% by sludge and 0.1% by volatilization to air; estimated) [b] | U.S. EPA (2012) | Not Rated |
| | Between 50 and >95% during biological wastewater treatment and removal | Clara et al. (2011) | High |
| Bioconcentration factor | 1,584 (whole fish, wet weight) bluegill sunfish (*Lepomis macrochirus*) OECD Test guideline 305E | NLM (2018) citing Balk and Ford (1999) | High |
| | 624 (wet weight); 33,200 (lipid) zebrafish, (OECD Test guideline 305E | ECB (2008b) citing Butte and Ewald (1999) | High |
| Bioaccumulation factor | 52,370 (crucian carp)<br>66,030 (common carp)<br>39,400 (silver carp) | Hu et al. (2011) | High |
| Soil organic carbon:water partition coefficient (log $K_{OC}$) | 4.85 (19% organic content) | RIVM (1997) | High |
| | 3.6–3.9 | ECB (2008b) citing Muller et al. (2002) | Not Rated |
| | 3.8 | ECB (2008b) citing Artola-Garciana (2002) | Not Rated |

[a] Measured unless otherwise noted
[b] EPI Suite™ physical property inputs: Log $K_{OW}$ = 5.90, boiling point = 325 °C, melting point = −5 °C, vapor pressure = 0.000545 mm Hg, water solubility = 1.75 mg/L, biodegradation half-life (in hours) in the primary clarifier of a sewage treatment plant (STP; BioP) = 10,000, biodegradation half-life (in hours) in the aeration vessel of an STP (BioA) = 10,000 and biodegradation half-life (in hours) in the final settling tank of an STP (BioS) = 10,000, Simplified Molecular-Input LineEntry System (SMILES): O(CC(c(c1cc(c2C(C3C)(C)C)C3(C)C)c2)C)C1

HHCB lacks hydrolyzable functional groups and has been shown to have no biodegradation within 28 days in aerobic conditions. As such, HHCB is not expected to degrade in water. When present in surface water, HHCB will preferentially partition to suspended organic matter and sediments (consistent with low solubility [1.75 mg/L] and log $K_{OC}$ [3.6–4.5]). HHCB has been detected in surface waters regularly throughout the United States. See the Draft HHCB Environmental Exposure Assessment TSD for further information (U.S. EPA, 2026s).

In surface water, HHCB bioaccumulates in aquatic organisms. HHCB bioaccumulation varies widely among fish species, with reported bioaccumulation factors ranging from 624 (wet weight; zebrafish) to 66,030 (common carp). This variation reflects differences in lipid content and aligns with random catch samples from around the United States showing variable fish-tissue concentrations. For this Draft Risk Evaluation for HHCB, an OECD guideline bioconcentration factor (BCF) of 1,584 was selected as representative given its regulatory use and alignment with international standards. The Agency has high confidence in this value. However, EPA also recognizes the extensive variation in potential accumulation factors (U.S. EPA, 2026s).

HHCB can enter animals through direct uptake from water across respiratory surfaces (*e.g.,* gills in aquatic organisms) or through oral ingestion of contaminated food, water, or sediment through the alimentary canal (Arnot and Gobas, 2006). An OECD study (Van Dijk, 1996) has shown that within fish, HHCB will partition to the non-edible fractions (*i.e.,* gills and entrails) preferentially compared to the edible fractions (*i.e.,* muscle tissue). HHCB has also been found in livers of other organisms that dwell in aquatic habitats. Once accumulated, HHCB is expected to be metabolized to form more polar, excretable compounds (*i.e.,* HHCB-lactone).

HHCB is released into surface water bodies after partial removal (up to 95%) during wastewater treatment (see Figure 1-3). Removal efficiencies for wastewater treatment can vary widely (between 50 and >95%) based on the wastewater treatment (WWT) plant size, population served, product use behaviors, and treatment technologies. HHCB removal in these facilities is primarily attributed to sorption to sludge based on its low water solubility (1.75 mg/L), high Log $K_{OW}$ (5.9), and available monitoring data. See the Draft HHCB Environmental Exposure Assessment TSD for further information on wastewater treatment (U.S. EPA, 2026s). For this assessment, data on the half-life of HHCB in sediments was lacking. As such, the Agency is using a half-life of 9,999 days at 25 °C for modeling sediment concentrations. This value is high and represents a worst case-scenario appropriate for a screening-level assessment.

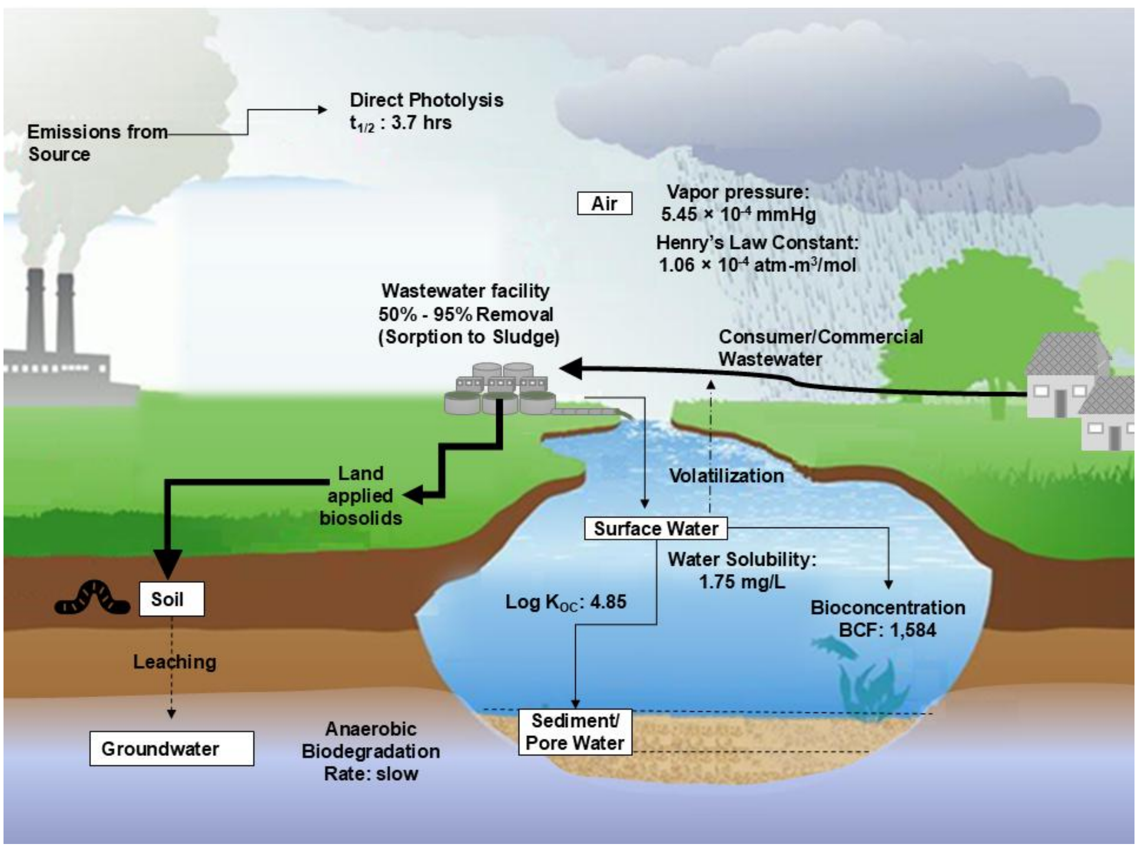


**Figure 1-3. Transport, Partitioning, and Fate of HHCB in the Environment**

When wastewater sludge is land applied as biosolids, HHCB may be found in soils. Due to its slow anaerobic biodegradation, HHCB may be present in such soils for more than 60 days and has been detected in monitoring studies (see Figure 1-3). Soil-dwelling organisms may be subject to bioaccumulation, but as described in the Draft HHCB Environmental Exposure Assessment TSD (U.S. EPA, 2026s), plants are not subject to biaccumulation.

Figure 1-3 summarizes the release of HHCB from industrial, consumer, and commercial products to wastewater treatment facilities (see Section 1.4) and how HHCB is transported in the environment. Arrow width qualitatively indicates relative partitioning (wider arrows = greater likelihood of movement), based on available physical and chemical, and environmental fate data. Key fate values are also overlaid on that figure.

### 1.3.3 Weight of Scientific Evidence Conclusions for Chemistry, Transport, and Environmental Fate

This assessment integrates multiple lines of evidence to characterize HHCB transport and fate, including physical and chemical properties, measured data from peer-reviewed studies, and available monitoring data. Inter-study consistency and individual study quality were evaluated; where discrepancies occurred, methodological differences were examined and protective endpoint values selected. Overall, this approach provides a robust basis for this draft HHCB risk evaluation.

## 1.4 Releases and Concentrations of HHCB in the Environment

HHCB is released through surface water discharges, land disposals, and air emissions. It does not persist in air and, while persistent in soil and groundwater, it is not expected to be mobile in these media (Section 1.3). This conclusion is supported by monitoring data and HHCB's physical and chemical properties as presented in Sections 2.3, 2.4, and Appendix D of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s). Accordingly, this risk characterization focuses on water-related releases: Either direct discharges to surface water at the waste-generating site or indirect discharges in which waste is transferred to publicly owned treatment works (POTWs) or WWT plants for further treatment prior to discharge. Transfer to POTWs may be referred to as "down-the-drain" releases because waste is typically conveyed through municipal sewer systems. This section summarizes the estimated releases and concentrations of HHCB in the environment; detailed approaches, methodologies, and results are provided in the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s).

### 1.4.1 Exposure Scenarios

For this draft risk evaluation, releases associated with COUs under the life-cycle stages of manufacturing, processing, and disposal are categorized as "industrial" releases. "Commercial" refers to releases from commercial uses whereas "consumer" refers to releases from consumer uses.

#### 1.4.1.1 Industrial

Table 1-4 and Table 1-5 provide crosswalks linking the HHCB COUs across the life cycle stages of manufacturing, processing, and disposal to the evaluated release scenarios (RSs). The five industrial RSs assessed are listed below:

- **Manufacturing:** releases from U.S. sites that produced HHCB (see Section 3.3.1 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Repackaging:** releases from sites that receive HHCB and repackage it into new containers, typically transferring material from large bulk transport containers to smaller containers; the repackaged product is then sold to formulators and other users (see Section 3.3.2 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Formulation of Fragrance Oils:** releases from sites that combine HHCB with other aroma chemicals to create specific scent blends; these blends are sent to customers who use them as commercial and consumer products (see Section 3.3.3 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

- **Formulation of End-Use Products:** releases from sites that add fragrance oils containing HHCB to a variety of products, including cleaning products, detergents, air fresheners, and candles (see Section 3.3.4 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Waste Handling, Treatment, and Disposal:** releases from waste management sites that receive HHCB-containing waste from sites that manufacture, process, or use HHCB (see Section 3.3.5 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

**Table 1-4. Crosswalk of Select Conditions of Use to Industrial Release Scenarios Assessed for HHCB**

| COU | | | Release Scenarios (RS)/ Occupational Exposure Scenarios (OESs) |
|---|---|---|---|
| **Life Cycle Stage** | **Category** | **Subcategory** | |
| Manufacturing | Domestic manufacturing | Domestic manufacturing | Manufacturing |
| | Importing | Importing | Repackaging |
| Processing | Processing – Incorporation into formulation, mixture or reaction product | Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials | ***Formulation of Fragrance Oils*** |
| | | | Formulation of End-Use Products |
| Processing | Processing – incorporation into articles | Odor agent in plastics material and resin manufacturing | Release Scenario: Formulation of End-Use Products<br>***OES: Plastics compounding/ converting*** |
| Processing | Repackaging | Odor agent in: All other chemical product and preparation manufacturing | Repackaging |
| Processing | Recycling | Recycling | Formulation of End-Use Products |
| Commercial | Other use laboratory chemicals | Laboratory chemicals | Not assessed as no facilities for use as a laboratory chemical were identified in TRI and releases to down-the-drain are expected to be minimal |
| Disposal | Disposal | Disposal | Waste Handling, Treatment, and Disposal |
| Distribution in commerce | Distribution in commerce | Distribution in commerce | Not assessed as no releases expected during transportation |

TRI = Toxics Release Inventory
***Bolded and italicized*** text: Release scenarios that are also assessed in the Occupational Exposure Assessment (Section 3.3.1).

The five bulleted RSs are linked to seven COUs, with some RSs informing multiple COUs. Links are based on the expected activities for each COU and the reasonably available data. For two COUs, release estimates were not quantified because those uses are expected to have low and infrequent water releases. Generally, RSs correspond directly to the occupational exposure scenarios (OES); that is, the conditions under which workers would be exposed. However, in some cases, the RS may differ from the OES. For example, as seen in Table 1-4, the Formulation of End-Use Products RS includes plants that produce plastic articles as well as other commercial and consumer use products, whereas the OES, Plastic compounding/converting isspecific to sites that produce plastic articles. Table 1-5 presents the crosswalk from RSs to COUs.

**Table 1-5. Crosswalk of Industrial Release Scenarios Assessed to Conditions of Use for HHCB**

| **Release Scenarios (RS)/ Occupational Exposure Scenarios (OESs)** | **COU** | | |
|---|---|---|---|
| | **Life Cycle Stage** | **Category** | **Subcategory** |
| Manufacturing | Manufacturing | Domestic manufacturing | Domestic manufacturing |
| Repackaging | Manufacturing | Importing | Importing |
| | Processing | Repackaging | Odor agent in: All other chemical product and preparation manufacturing |
| ***Formulation of Fragrance Oils*** | Processing | Processing – Incorporation into formulation, mixture or reaction product | Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials |
| Formulation of End-Use Products<br>***OES: Plastics compounding /converting*** | Processing | Processing – Incorporation into formulation, mixture or reaction product | Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials |
| | Processing | Processing – Incorporation into articles | Odor agent in plastics material and resin manufacturing |
| | Processing | Recycling | Recycling |
| Waste Handling, Treatment, and Disposal | Disposal | Disposal | Disposal |
| Qualitative assessment | Commercial use | Other use – Laboratory chemicals | Laboratory chemicals |
| | Distribution in commerce | Distribution in commerce | Distribution in commerce |
| ***Bolded and italicized*** text: RS Scenarios also assessed in the occupational exposure assessment (Section 3.3.1). | | | |

#### 1.4.1.2 Commercial (Down-the-Drain)

Table 1-6 provides a crosswalk linking COUs under the "Commercial use" life cycle stage to the evaluated RSs.

**Table 1-6. Crosswalk of Select Conditions of Use to Commercial Use Release Scenarios for HHCB**

| Life Cycle Stage | Category | Subcategory | Release Scenarios (RS)/ Occupational Exposure Scenarios (OESs) |
|---|---|---|---|
| Commercial use | Air care products | Air fresheners for motor vehicles<br>Continuous action air fresheners<br>Instant action air fresheners | Not assessed, releases are primarily expected to be to air and landfill |
| Commercial use | Cleaning and furnishing care products | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish<br>All-purpose liquid spray cleaner<br>All-purpose waxes and polishes<br>Appliance cleaners<br>Drain and toilet cleaners (liquid)<br>Powder cleaners (floors)<br>Powder cleaners (porcelain) | Use of liquid surface cleaners<br>Use of liquid toilet cleaners<br>Use of liquid carpet cleaners<br>Use of powder carpet cleaners |
| Commercial use | Laundry and dishwashing products | Laundry detergent (liquid)<br>Laundry detergent (unit dose/granule)<br>Fabric enhancers<br>Stain removers<br>Dishwashing detergent (liquid/gel)<br>Dishwashing detergent (unit dose/ granule)<br>Dishwashing detergent liquid (hand-wash) | Use of liquid laundry (detergent/softener) [a] products at industrial laundries<br>Use of liquid laundry (detergent/softener) [a] products at institutional laundries<br>Use of powder laundry (detergent/softener) [a] products at industrial laundries<br>Use of powder laundry (detergent/softener) [a] products at institutional laundries<br>Use of liquid dishwasher detergent<br>Use of powder dishwasher detergent<br>Use of hand dishwashing soap |
| Commercial use | Plastic and rubber articles not covered elsewhere | Plastic and rubber articles | Not assessed, these articles will be disposed of to landfill |
| Commercial use | Other use laboratory chemicals | Laboratory chemicals | Not assessed, releases to water are expected to be infrequent and low |

[a] EPA identified HHCB in fabric softener dryer sheets and professional stain remover used in laundries and dry cleaning. The Agency did not assess fabric softener dryer sheets as these are added after the washing step;

| Life Cycle Stage | Category | Subcategory | Release Scenarios (RS)/ Occupational Exposure Scenarios (OESs) |
|---|---|---|---|
| therefore, no releases of water are expected. EPA also did not model releases for the stain remover as no usage data for stain removers at industrial and institutional laundries were available from standard sources, so this product type was not separately assessed. | | | |

The 11 commercial RSs assessed (see Table 1-7) are listed below:

- **Use of Liquid Surface Cleaner:** releases from use by professional janitorial and housekeeping staff (see Section 3.4.3 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Liquid Toilet Cleaners:** releases from use by professional janitorial and housekeeping staff (see Section 3.4.3 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Liquid Carpet Cleaners and Use of Powder Carpet Cleaners:** releases from use by professional carpet- and upholstery-cleaning companies; janitorial staff may occasionally perform carpet cleaning, but it is not expected to be a daily activity (see Section 3.4.3 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Liquid Laundry Detergent/Softeners and Use of Powder Laundry Detergent/ Softeners at Industrial Laundries:** releases from use by industrial laundries that clean large quantities of textiles (*e.g.,* linens and work uniforms) (see Section 3.4.1 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Liquid Laundry Detergent/Softeners and Use of Powder Laundry Detergent/Softeners at Institutional Laundries:** releases from use by on-premise laundries in service-oriented facilities (*e.g.,* hotels, hospitals, nursing homes) (see Section 3.4.1 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Liquid Dishwasher Detergent and Use of Powder Dishwasher Detergent:** releases from machine washing at businesses such as restaurants and bars (see Section 3.4.2 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).
- **Use of Hand Dishwashing Soap:** releases from manual washing at businesses such as restaurants and bars (see Section 3.4.2 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

These release scenarios and two corresponding COUs were selected for this screening-level analysis because they are expected to generate frequent down-the-drain releases. Five COUs were not evaluated as any releases are expected to be relatively low and infrequent; thus, they are minor contributors to HHCB down-the-drain releases.

**Table 1-7. Crosswalk of Release Scenarios to COUs**

| Release Scenarios (RS)/ Occupational Exposure Scenarios (OESs) | COU | | |
|---|---|---|---|
| | **Life Cycle Stage** | **Category** | **Subcategory** |
| Use of Liquid Surface Cleaners | Commercial use | Cleaning and furnishing care products | All-purpose foam spray cleaner<br>All-purpose liquid cleaner/polish<br>All-purpose liquid spray cleaner<br>All-purpose waxes and polishes<br>Appliance cleaners<br>Drain and toilet cleaners (liquid)<br>Powder cleaners (floors); Powder cleaners (porcelain) |
| Use of Liquid Toilet Cleaners | | | |
| Use of Liquid Carpet Cleaners | | | |
| Use of Powder Carpet Cleaners | | | |
| Use of Liquid Laundry (Detergent/Softener) Products at Industrial Laundries | Commercial use | Laundry and dishwashing products | Laundry detergent (liquid)<br>Laundry detergent (unit dose/granule)<br>Fabric enhancers<br>Stain removers<br>Dishwashing detergent (liquid/ gel); Dishwashing detergent (unit dose/granule)<br>Dishwashing detergent liquid (hand-wash) |
| Use of Liquid Laundry (Detergent/Softener) Products at Institutional Laundries | | | |
| Use of Powder Laundry (Detergent/Softener) Products at Industrial Laundries | | | |
| Use of Powder Laundry (Detergent/Softener) Products at Institutional Laundries | | | |
| Use of Liquid Dishwasher Detergent | | | |
| Use of Powder Dishwasher Detergent | | | |
| Use of Hand Dishwashing Soap | | | |
| Qualitative Assessment | Commercial use | Air care products | Air fresheners for motor vehicles |
| | Commercial use | Air care products | Continuous action air fresheners |
| | Commercial use | Air care products | Instant action air fresheners |
| | Commercial use | Plastic and rubber articles not covered elsewhere | Plastic and rubber articles |
| | Commercial use | Other use laboratory chemicals | Laboratory chemicals |

#### 1.4.1.3 Consumer (Down-the-Drain)

Consumers generate down-the-drain releases of HHCB from residential cleaning, dishwashing, and laundry (Table 1-8). At the municipal scale, these releases combine at a single POTW, which treats and discharges effluent containing HHCB. Product types parameterized within the Stochastic Human Exposure Dose Simulation - High Throughput (SHEDS-HT) Model (ICF, 2024) that fall within these COUs were identified to estimate release amounts (Table 1-9).

**Table 1-8. Consumer Use COUs Assessed in Down-the-Drain Analysis**

| Life Cycle Stage[a] | Category | Subcategory |
|---|---|---|
| Consumer use | Cleaning and furnishing care products | All-purpose foam spray cleaner<br>All-purpose liquid cleaner/polish<br>All-purpose liquid spray cleaner<br>All-purpose waxes and polishes<br>Appliance cleaners<br>Drain and toilet cleaners (liquid)<br>Powder cleaners (floors)<br>Powder cleaners (porcelain) |
| Consumer use | Laundry and dishwashing products | Laundry detergent (liquid)<br>Laundry detergent (unit dose/granule)<br>Fabric enhancers<br>Stain removers<br>Dry cleaning and associated products<br>Dishwashing detergent (liquid/gel)<br>Dishwashing detergent (unit dose/granule)<br>Dishwashing detergent liquid (hand-wash) |

**Table 1-9. Consumer Product Types Parameterized in SHEDS-HT Selected to Represent Consumer Use COUs for Down-the-Drain Loading**

| SHEDS-HT Product Code (Source.id) | SHEDS-HT Product Name (Source.description) |
|---|---|
| Products included in TSCA COUs | |
| P.IH.040.999 | Bathroom cleaner-NOC |
| P.IH.070.029 | Carpet cleaner-spray |
| P.IH.070.999 | Carpet cleaner-NOC |
| P.IH.080.000 | Carpet deodorizer |
| P.IH.090.000 | Dish soap |
| P.IH.260.013 | Laundry detergent-liquid |
| P.IH.260.023 | Laundry detergent-powder |
| P.IH.260.999 | Laundry detergent-NOC |
| P.IH.270.000 | Laundry fragrance |
| P.IH.280.999 | Laundry stain remover-NOC |
| P.IH.340.999 | Surface cleaner-NOC |
| P.PT.060.999 | Pet stain cleaner-NOC |

| SHEDS-HT Product Code (Source.id) | SHEDS-HT Product Name (Source.description) |
|---|---|
| NOC = not otherwise classified; SHEDS-HT = Stochastic Human Exposure Dose Simulation - High Throughput Model | |

### 1.4.2 Summary of Environmental Releases

#### 1.4.2.1 Industrial

For industrial releases, TRI data for the reporting year 2023 was used, in which 65 facilities submitted release information. Most reports indicated no releases of HHCB to water either directly discharged at their facility or sent to POTW or private WWT facility. At sites that reported water releases, it was only indirectly discharged through transfers primarily to POTWs. The highest estimated daily transfer was from a facility that manufactures HHCB, with an estimated 9 kg/day-site of HHCB sent to a POTW.

As TRI data provides only annual quantities, an assumption of 240 or 250 days of release depending on the RS were applied to derive daily transfer rates. These assumptions were based on information from industry submissions (FCA, 2021) and professional judgements on operating days for each RS (See Section 3.2.5 in the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)). Notably, TRI does not include releases from commercial or consumer uses. Additionally, POTWs (NAICS 221320) are not among the industries required to report to TRI and no Discharge Monitoring Report (DMR) data was available for HHCB to supplement the release assessment. Relevant HHCB release data from the 2023 TRI and daily transfer rate calculations are presented in *Draft Summary of Toxics Release Inventory (TRI) for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ae) and are summarized below in Table 1-10.

**Table 1-10. Annual and Daily HHCB Water Release Rates Based on 2023 TRI**

| Scenario | Number of Facilities | Number of Facilities Without Water Releases | Number of Facilities with Water Releases | Range of Annual Releases (kg/yr-site) | Range of Daily Releases (kg/day-site) | Type of Discharge |
|---|---|---|---|---|---|---|
| Manufacturing | 2 | 1 | 1 | 2,226 | 9 | Indirect discharge to POTW |
| Repackaging | 1 | 0 | 1 | 21 | 0.08 | Indirect discharge to POTW |
| Formulation of Fragrance Oils | 12 | 6 | 6 | 3–340 | 0.01–1.42 | Indirect discharge to POTW |
| Formulation of End-Use Products | 35 | 24 | 8[a] | 0.09–23 | 3.6E−04 to 0.09 | Indirect discharge to POTW |
| | | | 4[a] | 0.09–1,196 | 3.6E−04 to 4.78 | Indirect discharge to WWT |
| Waste Handling, Treatment, and Disposal | 2 | 2 | 0 | – | – | – |
| Total | 52[b] | 33 | 19 | 0.09–2,226 | 3.6E−04 to 9 | Indirect discharge to POTW or WWT |
| POTW = publicly owned treatment works; WWT = wastewater treatment<br>[a] One site has both indirect discharges to a POTW and a WWT facility. | | | | | | |

| Scenario | Number of Facilities | Number of Facilities Without Water Releases | Number of Facilities with Water Releases | Range of Annual Releases (kg/yr-site) | Range of Daily Releases (kg/day-site) | Type of Discharge |
|---|---|---|---|---|---|---|
| [b] Thirteen facilities were not assigned to a scenario because a review of the companies and site locations indicated that the activities occurring with HHCB may be non-TSCA; that is, related to the manufacturing of cosmetics, hair care, and other personal care products. | | | | | | |

#### 1.4.2.2 Weight of Scientific Evidence Conclusion for Environmental Releases from Industrial Sources

For weight of scientific evidence conclusions, the assessment approach, data and model quality, and uncertainties were evaluated to determine a level of confidence in the release estimates. All scenarios except repackaging have a moderate weight of scientific evidence conclusion. Repackaging has a slight-to-moderate conclusion due to higher uncertainties in its representativeness of its results to all the repackaging of HHCB that may occur in the United States. For each RS, the full rationales for the weight of scientific evidence conclusions are provided in Section 3.6.1 of the Draft Environmental Exposure Assessment (U.S. EPA, 2026s).

For industrial releases, release estimates relied on TRI submissions with an assumed number of release (transfer) days applied to calculate daily release rates. The TRI data has a medium data quality rating under EPA's systematic review process, which strengthens the approach. It is based on company reported estimates using their knowledge of their process conditions with a variety of methods to calculate the amount of HHCB sent to POTWs or WWT facilities. Most submitters relied on published emission factors or mass balance calculations to estimate the amounts of HHCB.

This assessment relies on the first year of reporting for HHCB under the TRI program. A single year of data introduces some uncertainty as manufacturing and processing of HHCB may vary year to year due to shifts in use of HHCB. A single year of release information may fail to capture that variability or changes in management methods of waste. A comparison with the preliminary TRI data for 2024 showed increases in the number of sites (22 additional sites) and increases in the total amount of HHCB water releases (+7,737 kg/yr-all-sites). This increase is mostly driven by a few new reporters in the 2024 dataset. While there were no sites that directly discharge on-site in 2023, there was one site in 2024 that had on-site water discharges. These changes demonstrate that there can be variations in the amount transferred and the method of discharges year to year (see changes by RS in Appendix B of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

For HHCB, the TRI reporting threshold is 100 lb. This is a lower threshold (because it is classified under TRI as persistent, bioaccumulative, and toxic) than for most chemicals (25,000 lb. for manufacturing and processing; 10,000 lb for otherwise use) and therefore captures a more representative distribution of releasing facilities. The representativeness of this distribution conveys more confidence in the risk characterization. However, because TRI reporting also applies only to facilities with 10 or more full-time employees, some small-size manufacturers and processers may not be captured.

The number of release days is based on the lowest reported operating days from a Fragrance Creators Association (FCA) survey of fragrance oil and end-use product formulators, who also indicated that HHCB may not be used every operating day. Therefore, some uncertainty exists with the assumption that the operating schedule is consistent with the number of days that HHCB-containing waste was released to POTWs. Lower release days would cause higher daily release rates. Therefore, the estimates may underestimate the daily release rate of HHCB to POTWs.

Some of the scenarios only had two or less sites identified through the TRI database. For some scenarios, it may still be representative of the industry based on a low expected number of sites performing the activity in the United States such as for manufacturing. For repackaging, the low number of sites (n = 1) is a limitation as it is unknown the total number of sites repackaging HHCB in the United States. The low reporting threshold for HHCB (>100 lb) increases confidence in capturing sites likely repackaging the largest quantities of HHCB. However, because TRI reporting also applies only to facilities with 10 or more full-time employees, some repackaging sites with limited staff may not be captured.

#### 1.4.2.3 Commercial (Down-the-Drain)

Table 1-11 presents annual and daily release rates for the assessed commercial products.

**Table 1-11. Daily and Annual Water Release Rates of HHCB from Commercial Uses**

| Product Category | Product Type | Daily Release Rates (kg/day-site) | | Annual Release Rates (kg/yr-site) | |
|---|---|---|---|---|---|
| | | CT | HE | CT | HE |
| Laundry Products [Industrial Laundries] [a] | Liquid detergent | 1.28E−02 | 2.56E−01 | 2.59E00 | 5.45E01 |
| | Liquid softener | 2.10E−03 | 1.15E−02 | 4.31E−01 | 2.70E00 |
| | Powder detergent | 4.74E−02 | 5.47E−01 | 9.46E00 | 1.22E02 |
| | Powder softener | 8.12E−03 | 5.84E−02 | 1.63E00 | 1.53E01 |
| Laundry Products [Institutional Laundries] | Liquid detergent | 7.22E−03 | 2.60E−01 | 1.44E00 | 5.71E01 |
| | Liquid softener | 1.55E−03 | 1.54E−02 | 3.43E−01 | 3.50E00 |
| | Powder detergent | 3.35E−03 | 2.75E−02 | 6.92E−01 | 5.84E00 |
| | Powder softener | 7.83E−03 | 3.30E−02 | 1.50E00 | 7.81E00 |
| Cleaning Products | Liquid surface cleaners | 1.21E−02 | 6.43E−02 | 3.55E00 | 1.90E01 |
| | Liquid toilet cleaners | 2.09E−03 | 8.49E−03 | 6.15E−01 | 2.52E00 |
| | Liquid carpet cleaners | 2.27E−03 | 6.13E−03 | 2.27E−03 | 6.13E−03 |
| | Powder carpet cleaners[b] | 2.20E−03 | 6.60E−03 | 2.20E−03 | 6.60E−03 |
| Dishwashing Products | Liquid dishwasher detergent | 4.79E−03 | 6.22E−03 | 1.67E00 | 2.18E00 |
| | Powder dishwasher detergent | 2.49E−04 | 3.70E−04 | 8.72E−02 | 1.29E−01 |
| | Liquid dish soap (hand) | 5.08E−03 | 6.97E−03 | 1.78E00 | 2.44E00 |

CT = central tendency; HE = high-end
[a] Additional additive scenario where detergent and softener both contain HHCB, these values are provided in the *Draft Environmental Release Modeling for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026t)
[b] Powder carpet cleaner was not modeled using Monte Carlo simulations. The central tendency represents the lower bound and the high-end represents the upper bound calculating using the minimum and maximum concentration levels identified.

***Laundry Detergents and Softeners***

Releases from the commercial use of laundry detergents and softeners were modeled using industry data from the OECD emission scenarios document (ESD) Chemicals Used in Water Based Washing Operations at Industrial and Institutional Laundries (OECD, 2011). The model ran 100,000 Monte Carlo simulations, sampling from the full distribution of facility types, use rates, and release days reported in the ESD, combined with HHCB-specific concentration data. HHCB concentrations were sourced from safety data sheets (SDSs) for a commercial fabric softener and consumer laundry detergents; no concentration data were identified for commercial laundry detergents.

The highest daily releases of HHCB come from the commercial uses of laundry detergents and softeners at industrial and institutional laundries with daily releases up to 547 g/day-site. These facilities process large volumes of laundry products each day with the highest HHCB concentration (up to 0.9% w/w) among the commercial products assessed (see Section 3.4.1 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

***Surface, Toilet, and Carpet Cleaners***

For surface, toilet, and carpet cleaners, no relevant industry data were available in ESDs or generic scenarios (GS). Therefore, supplemental sources were investigated. Daily releases generally assume that most cleaners used are discarded down-the-drain to POTWs. Daily usage rates for surface cleaners were estimated by modeling floor-cleaner use, using the occupied floor-area data for commercial buildings from EPA's Buildings Assessment Survey and Evaluation Study (BASE) (U.S. EPA, 2023b) and an application rate of floor-cleaning solution per unit surface area from National Institute for Public Health and the Environment [Netherlands] (RIVM) Consumer Cleaning Products Fact Sheet (RIVM, 2018).

Usage rate (per toilet) for toilet cleaners was taken from the RIVM fact sheet. These rates were combined with occupancy data from the EPA BASE study and recommended toilet-per-occupant ratio to generate a distribution for the number of toilets per commercial building. For floor and toilet cleaner products, the distribution of release days ranged from 260 days per year (5 days per week for 52 weeks) to a maximum of 365 days per year.

Professional upholstery and carpet-cleaning businesses may use carpet cleaners containing HHCB. Daily release rates for these products will vary because these companies service different job sites each day, including commercial buildings and residential homes. Typical release rates for liquid carpet cleaners were estimated from the volume of product used per a typical carpet-cleaning machine, assuming a job uses the full reservoir of the machine. The cleaner dose was then determined using label-recommended dilution ratios for a carpet-cleaner product. For powder cleaners, use was assumed to be primarily for smaller areas; therefore, a usage rate was estimated from a generic powder carpet cleaner (*i.e.,* does not contain HHCB) for a total applied surface area of 22 $m^2$ (≈237 $ft^2$).

Notably, no HHCB-specific concentration data were available for surface (floor) or carpet cleaners; however, it was available for bathroom/toilet cleaners. These concentrations from bathroom/toilet cleaners (0.1–0.3% w/w) were used for floor and carpet cleaners.

Among cleaning products, surface cleaners have the highest estimated release rates – approximately 12-64 g/day-site (see Section 3.4.3 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

***Dishwashing Products***

Three dishwashing products were modeled: liquid dishwasher detergent, powder dishwasher detergent and hand dish soap. Limited industry data was available, therefore an approach using Consumer Exposure Model (CEM) defaults were applied and scaled up for occupational use. For liquid dishwasher detergents, the per-cycle usage rate was scaled up by a factor of 160, based on a public comment from industry indicating that commercial establishments typically run 160 cycles per day (P&G, 2023). For hand dishwashing and powder dishwasher detergents, consumer usage amounts were scaled up to the amount used if the activities continued for an 8-hour operation. Releases are assumed to occur 7 days/week, 50 weeks/year (350 days/year).

Daily release rates from dishwashing products were relatively low, with powder dishwasher products releasing less than 1 g/day-site of HHCB. For liquid dishwasher detergent and hand dish soap, rates were comparable to use of cleaning products, at approximately 4 to 7 g/day-site (see Section 3.4.2 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s)).

#### 1.4.2.4 Population-Scaled Commercial Releases

Because the influent stream to a POTW contains HHCB from a combination of commercial and consumer uses, the following two different scenarios were considered to account for commercial releases:

- Commercial-only use COUs (Cleaning and furnishing care products, Laundry and dishwashing products) generating down-the-drain HHCB releases from product usage in multiple commercial settings (at hotels, laundromats, hospitals, restaurant kitchens, and other business types) across a municipality, which are combined at a single POTW.
- Commercial-only (multiple sites) and consumer-only (multiple sites) generating down-the-drain HHCB releases that combine at a single POTW.[2]

To understand how many sites may feed into a single POTW, an approach to tie prevalence of businesses to population size. First, U.S. Census Bureau data (U.S. Census Bureau, 2021) was used to estimate the number of businesses expected to use commercial products daily, based on the 6-digit NAICS code. The approach divides the total number of sites within each industry code by the U.S. population, yielding a national average per-capita prevalence rate for each facility type, which was used for the commercial down-the-drain analysis. A summary of the resulting prevalence rates is provided in Table 1-12.

**Table 1-12. Summary of per Capita (10k) Prevalence of Sites in Business Categories Associated with Commercial Down-the-Drain Releases, Derived from Census Data**

| Business Category | Primary TSCA Products | NAICS Code(s) | Businesses (per 10,000 People) |
|---|---|---|---|
| Janitorial Services | Toilet cleaners, surface cleaners, carpet cleaners | 561720 | 2.0 |
| Carpet and Upholstery Cleaning Services | Carpet cleaners | 561740 | 0.21 |
| Hospitals | Toilet cleaner, surface cleaner, carpet cleaner, laundry detergent- institutional, laundry softener- institutional | 622110, 622210, 622310 | 0.22 |

[2] In practice, commercial and consumer release co-occur at the same POTW producing combined downstream HHCB exposure from both sources.

| Business Category | Primary TSCA Products | NAICS Code(s) | Businesses (per 10,000 People) |
|---|---|---|---|
| Nursing Facilities | Toilet cleaner, surface cleaner, carpet cleaner, laundry detergent- institutional, laundry softener- institutional | 623110, 623210, 623220, 623311, 623312, 623990 | 2.88 |
| Lodgings | Toilet cleaner, surface cleaner, carpet cleaner, laundry detergent- institutional, laundry softener- institutional | 721110, 721120, 721191, 721199, 721310 | 1.9 |
| Food Service | Dishwashing products | 722310, 722320, 722330, 722410, 722511, 722513, 722514, 722515 | 20.3 |
| Drycleaning and Laundry Services | Laundry detergent – industrial, laundry softener – industrial | 812320, 812331, 812332 | 0.58 |
| Note: Appendix F contains the per capita estimates for each NAICS code as well as the total number of U.S. establishments<br>Total U.S. Population (2020 Census): 331,449,281 | | | |

For example, based on U.S. average business statistics, a POTW serving a population of 38,000 people would be expected to receive releases from the following facilities:

- 8 Janitorial Services businesses (*e.g.,* office cleaners);
- 1 Carpet and Upholstery Cleaning Services businesses;
- 1 Hospital;
- 11 Nursing Facilities (*e.g.,* nursing homes, intermediate care facilities);
- 7 Lodgings businesses (*e.g.,* hotels);
- 77 Food Services businesses (*e.g.,* restaurants); and
- 2 Dry Cleaning and Laundry Services businesses.

These estimates of the numbers of commercial sites were applied to the populations of the representative POTW release scenarios described in Appendix F and in the Draft HHCB Environmental Exposure Assessment Appendix F (U.S. EPA, 2026s). These values are used as further described in Section 1.4.3.1. Additional detail on facility types and prevalence is provided in Appendix F, along with the analysis methods, intermediate values and results.

#### 1.4.2.5 Weight of Scientific Evidence Conclusion for Environmental Releases from Commercial Sources

For weight of scientific evidence conclusions, the assessment approach, the data and model quality, and the uncertainties were evaluated in the assessment results to determine a level of confidence in the release estimates. All scenarios have a moderate weight of scientific evidence conclusion. For each RS, the full rationales for the weight of scientific evidence conclusions are provided in Section 3.6.1 of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s).

Water releases were assessed using EPA/OPPT models and assumptions on daily use rates combined with Monte Carlo modeling to estimate releases to the environment. Based on the type of products and application, HHCB used is expected to primarily go down-the-drain during application. The underlying sources used to predict the amount of HHCB used per day of application were EPA BASE study (U.S. EPA, 2023b), RIVM Factsheet on Cleaning Products (RIVM, 2018), ESD on Water-based Washing

Operations at Industrial and Institutional Laundries (OECD, 2011), defaults in the EPA/OPPT CEM model (U.S. EPA, 2023a), a public comment from industry (P&G, 2023), and product instruction information. These references received data quality ratings between medium to high and have clearly documented sources, approaches and assumptions, and are considered a strength in this approach.

Monte Carlo modeling was a strength of this assessment as it captures variations in model input values and a range of potential release values are more likely to capture actual releases than discrete values. It also considers many data points (simulation runs) and the full distributions of input parameters (see modeling details in Appendix C of the Draft Environmental Exposure Assessment (U.S. EPA, 2026s)).

Chemical-specific concentrations and product instruction information for commercial products were used where available; however, in some cases, consumer or surrogate product types were utilized which is a limitation. For example, data from a commercial fabric softener product was used but no commercial laundry detergent data was identified therefore consumer laundry detergents were used instead. For dishwashing products, a consumer liquid hand dish soap was used for all product types as it was the only concentration data found. Although commercial products are typically more concentrated than consumer products, fragrance content may be lower or absent in commercial products likely to avoid the presence of allergens (*e.g.,* fragrance) for public use. In addition, the concentrations identified through consumer product SDSs tended to be higher than reported from industry submissions. For this screening-level assessment, using the higher values is suitable but it may overestimate the releases if HHCB concentration in commercial products are lower.

For the combined down-the-drain analysis for commercial products, the lack of prevalence data for HHCB for the product types is an uncertainty. The current approach assumes that all applicable facilities use products containing HHCB, which depends on how prevalent use of HHCB is for each product type. This is slightly offset by considering that only a limited list of facility types was considered while use of some of these products cover more industries than studied. Additionally, in some cases, relevant product types were not estimated due to difficulty estimating commercial usage rates such as the use of multi-surface or bathroom cleaners. This factor leads to potential underestimation of the loading to POTW for the combined down-the-drain analysis.

#### 1.4.2.6 Consumer (Down-the-Drain)

Residential use of HHCB-containing consumer products (*e.g.,* laundry detergents, dishwashing detergents, surface cleaners) results in down-the-drain releases to local POTWs. Combined community-scale releases were modeled, as described in the Draft Environmental Exposure Assessment (U.S. EPA, 2026s). Because direct POTW discharge data for HHCB are not available for consumer COUs, consumer down-the-drain releases were estimated using EPA's Stochastic Human Exposure and Dose Simulation - High Throughput (SHEDS-HT v0.1.10) (ICF, 2024). SHEDS-HT is a probabilistic (Monte Carlo) platform that simulates individual-day activity patterns and product-use events, using inputs such as product concentrations, use frequency and amount, physical and chemical properties, and life-stage/sex-specific behavior patterns. Outputs characterize population variability and can incorporate parameter uncertainty. Product data from the *Product Concentration Data Masterlist for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2025b) served as inputs. HHCB weight fractions varied by product types and individual product and are typically near 0.1% (1 g/kg). The mean daily per capita loading to wastewater modeled by SHEDS-HT for each product type was summed to yield a combined consumer loading of 1.07 g/person/day (Table 1-13). These release totals include conservative assumptions of product usage, prevalence of HHCB-containing products, and product HHCB weight fractions that bias the results toward higher estimates when scaled in this screening analysis.

**Table 1-13. Consumer Product Mean Per Capita Down-the-Drain Releases Modeled in SHEDS-HT**

| Product Classification | Mean Down-the-Drain Loading (mg/day per capita) |
|---|---|
| Surface Cleaner (including floor cleaner) | 42.0 |
| Dish Soap | 23.0 |
| Laundry Detergent | 15.6 |
| Bathroom Cleaner | 10.6 |
| Carpet Cleaner Other | 7.49 |
| Fragrance | 2.93 |
| Pet Stain Cleaner | 2.57 |
| Carpet Deodorizer | 1.65 |
| Laundry Stain Remover | 1.03 |
| Laundry Fragrance | 0.09 |
| Carpet Cleaner Spray | 0.05 |

Population-average product loadings modeled with SHEDS-HT were combined with POTW data from the Clean Watershed Needs Survey (CWNS) (U.S. EPA, 2025a) to characterize the distribution of surface water HHCB concentrations resulting from consumer product use and treated-wastewater discharges. The POTW scenarios used are based on a combination of the contributing population, level of treatment, and receiving water body flow, to predict the relative ranking of resulting environmental media concentrations. Further discussion of the development and application of these POTW scenarios can be found in Section 4.2.2 and Appendix F of the Environmental Exposure TSD. The P95 and P50 POTW release scenarios (Table 1-14) were applied, along with the per capita HHCB loadings modeled with SHEDS-HT, to be modeled in EPA's Point Source Calculator (PSC v1.05; (U.S. EPA, 2019b), and the resulting concentrations are carried forward for exposure and risk analyses.

**Table 1-14. Characteristics of Representative POTW Release Scenarios for Down-the-Drain Surface Water Releases of HHCB**

| POTW Release Scenario | Contributing Population | Receiving Waterbody 7Q10 Flow (MLD) | Receiving Waterbody 30Q5 Flow (MLD) | Receiving Waterbody HM Flow (MLD) | Removal Efficiency Applied (%) |
|---|---|---|---|---|---|
| P95 | 38,000 | 17.3 | 17.3 | 20.7 | 92 |
| P50 | 950,000 | 1,260 | 1,260 | 1,260 | 99 |

7Q10 = lowest 7-day average flow that occurs (on average) once every 10 years; 30Q5 = lowest 30-day average flow that occurs (on average) once every 5 years; MLD = million liters per day
Note: Flow rates are identical across some metrics due to substituting the facility effluent flow rate for the receiving water body flow, where the facility effluent flow rate exceeds the hydrologic flow in the receiving water.

#### 1.4.2.7 Weight of Scientific Evidence Conclusions for Environmental Releases from Consumer (Down-the-Drain) Sources

Water releases were evaluated under the assumption that consumer uses of the products listed in Table 1-13 result primarily in down-the-drain releases. Environmental releases were estimated using SHEDS-HT, together with assumptions about daily use patterns. Daily use rates were derived from defaults in the CEM (U.S. EPA, 2023a). The use of the Monte Carlo modeling in SHEDS-HT is considered a strength of the assessment, as variation in input values and the resulting range of potential releases are more likely to capture actual conditions than discrete point estimates. Monte Carlo modeling also incorporates large numbers of simulation runs and the full distributions of input parameters.

Product-specific HHCB concentrations from consumer products were used; however, available data were limited to products explicitly listing HHCB as an ingredient. The primary limitation is uncertainty in the prevalence of HHCB across consumer products (*i.e.,* the fraction of products containing HHCB), for which data are not readily available.

Although each individual consumer down-the-drain input (product usage, HHCB weight fractions, and assumed prevalence) is plausible, the compounding conservative assumptions yield national release estimates that are biased high. For example, extrapolating an average disposal rate of approximately 0.1 g/person/day to a full year for the entire U.S. population results HHCB down-the drain HHCB releases exceeding the total U.S. production volume. Although an individual could readily reach 0.1 g/day, this rate is not representative of national average for the entire population.

Based on this information, the weight of scientific evidence for the consumer-use COUs is moderate, and these analyses are likely to overestimate exposures due to compounding conservative factors, which is appropriate for use in a screening analysis.

### 1.4.3 Summary of Environmental Concentrations

#### 1.4.3.1 Surface Water Pathway

HHCB concentrations in surface water and sediment were estimated for four scenarios (described in the subsections below) for TSCA COUs that release HHCB to surface waters. This approach was used because the available monitoring, while informative, cannot be attributed to specific TSCA COUs, and may not be representative of the national distribution of concentrations at the point of release. The four release scenarios are introduced here and detailed methods for each are presented in the sections that follow:

- **Industrial Releases:** Manufacturing and Processing COUs transfer HHCB-containing wastewater to offsite treatment facilities (POTWs or commercial), which are assumed to treat it and discharge HHCB-containing effluent to surface water (Figure 1-4).


**Figure 1-4. Graphical Summary of Modeled Industrial Surface Water Release Scenario**

- **Commercial Down-the-Drain:** Commercial use COUs (Cleaning and furnishing care products, Laundry and dishwashing products) generate down-the-drain HHCB releases from product usage in commercial settings (at hotels, laundromats, hospitals, restaurant kitchens, and other business types) across a municipality, which combine to a single POTW that treats and discharges HHCB-containing effluent (Figure 1-5).

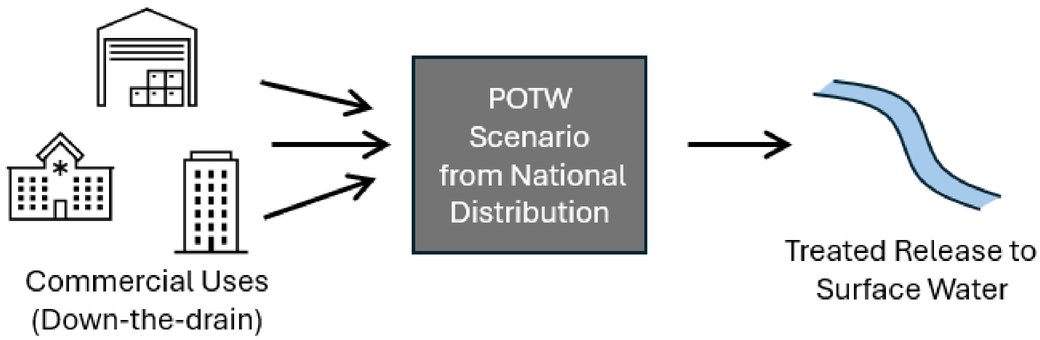


**Figure 1-5. Graphical Summary of Modeled Commercial Down-the-Drain Surface Water Release Scenario**

- **Consumer Down-the-Drain:** Consumer use COUs (Cleaning and furnishing care products, Laundry and dishwashing products) generate down-the-drain HHCB releases from residential use of cleaning, dishwashing, and laundry across a municipality, which combine to a single POTW that treats and discharges HHCB-containing effluent (Figure 1-6).

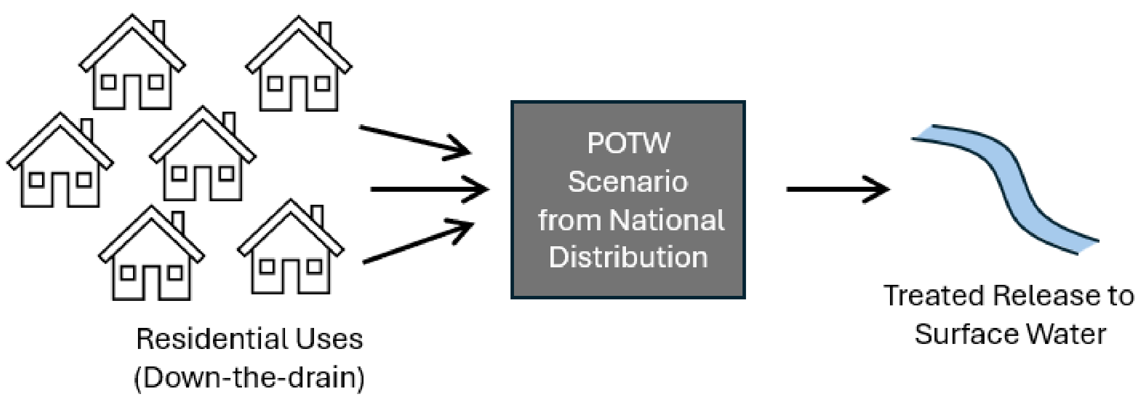


**Figure 1-6. Graphical Summary of Modeled Consumer Down-the-Drain Surface Water Release Scenario**

- **Aggregate Commercial Plus Consumer Down-the-Drain:** The two previous down-the-drain scenarios consider commercial-only or consumer-only releases to a single POTW, which then discharges to a receiving water body. In practice, commercial and consumer disposals co-occur at the same POTW, resulting in a combined release that ultimately drives exposure (Figure 1-7).

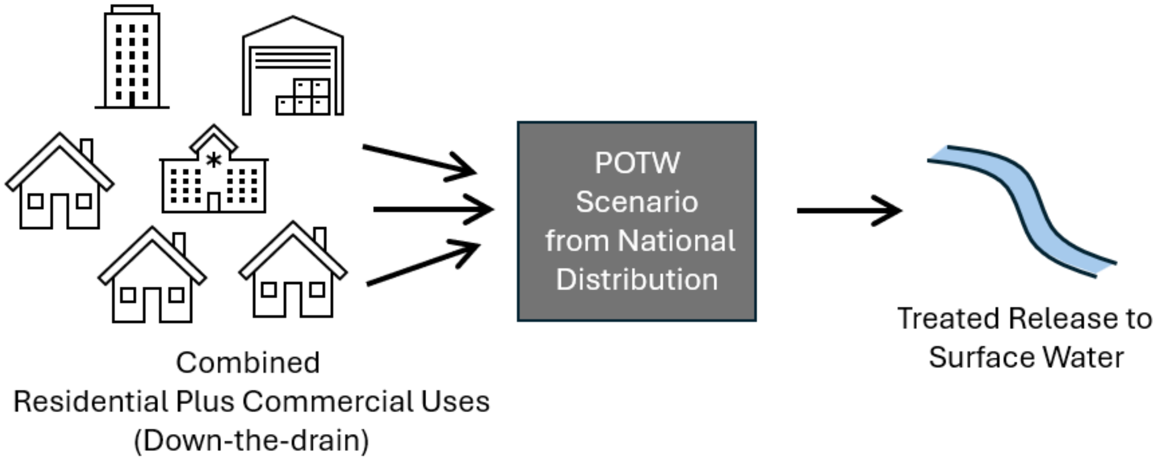


**Figure 1-7. Graphical Summary of Modeled Combined Commercial Plus Consumer Down-the-Drain Surface Water Release Scenario**

Environmental Release Scenario 4, which combines commercial and consumer down-the-drain modeling, was selected as the high-end exposure scenario prioritized for exposure modeling because it produces the highest modeled surface water concentrations of HHCB for a screening-level assessment. Commercial plus consumer down-the-drain receiving-water concentrations are modeled as combined releases to a single POTW using population-scaled average product use rates. POTW scenario characteristics are derived from CWNS data (U.S. EPA, 2025a) and reflect collection from multiple locations, treatment, and discharge from a single point source. Because communities include both residents and commercial businesses disposing of HHCB-containing products, combined loads were estimated by summing totals from preceding scenarios. Industrial releases were not included given the limited number of industrial discharges and relatively low contribution to POTW influent at known release locations. EPA's PSC v1.05 (U.S. EPA, 2019b)) and Variable Volume Water Model (VVWM) weres 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), release schedules, and receiving-water body parameters to simulate concentrations, evaluated at the discharge point. Results are summarized in Table 1-15, and these methods are described in further detail in the Draft HHCB Environmental Exposure Assessment (see Section 4.2.2.2 of that TSD).

For industrial releases, daily release estimates assume 92% WWTP removal prior to discharge and are reported in Table 4-7 of 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, 2026s). Modeled HHCB concentrations in surface water for industrial COUs under low-flow (7Q10; *i.e.,* the lowest 7-day average flow that occurs [on average] once every 10 years;) conditions ranged from 0.035 to 0.57 µg/L, and sediment concentrations ranged from 11 to 171 µg/kg. 30Q5 concentrations are equal to or less than 7Q10 concentrations. For each COU, the representative screening scenario corresponds to the facility with the maximum modeled surface water concentration or, where applicable, the sole facility with traceable releases to a flowing receiving water body. Maximum estimated concentrations occurred for the Manufacturing COU with an estuarine discharge; estuarine flow was conservatively approximated as the sum of the contributing stream flows, with additional tidal dilution excluded. These estimates are expected to be an overestimate but are appropriate for screening and are much lower than those estimated for combined down-the-drain exposures.

Table 1-15 reports modeled surface water and sediment concentrations from down-the-drain scenarios. Surface water 7Q10 concentrations range from less than 1 to 25.4 µg/L HHCB and sediment concentrations ranged from 87 µg/kg to 7,740 µg/kg. 30Q5 concentrations are equal to or less than 7Q10 concentrations. Estimates incorporate POTW treatment removal efficiencies of 92% (P95) and 99% (P50). Maximum concentrations occur under the combined consumer and commercial use scenario, reflecting population-level combination at a community POTW. The P95 scenario represents a high loading-to-receiving-flow ratio and is expected to exceed only 5% of POTWs nationwide for the down-the-drain loads in this assessment.

**Table 1-15. Combined Commercial Plus Consumer Down-the-Drain Estimated Water Column and Sediment Concentrations**

| Flow Metric | POTW Release Scenario | Down-the-Drain Scenario | Water Column Concentration (µg/L) | Sediment Concentration (µg/kg) |
|---|---|---|---|---|
| 7Q10 | P95 | Commercial | 6.62 | 2,010 |
| | | Consumer | 18.8 | 5,730 |
| | | Combined | 25.4 | 7,740 |
| | P50 | Commercial | 0.3 | 87 |
| | | Consumer | 0.8 | 246 |
| | | Combined | 1.11 | 333 |
| 30Q5 | P95 | Commercial | 6.62 | 2,010 |
| | | Consumer | 18.8 | 5,730 |
| | | Combined | 25.4 | 7,740 |
| | P50 | Commercial | 1.6 | 494 |
| | | Consumer | 6.46 | 1,970 |
| | | Combined | 8.1 | 2,460 |

7Q10 = lowest 7-day average flow that occurs (on average) once every 10 years; 30Q10 = lowest 30-day average flow that occurs (on average) once every 5 years; POTW = publicly owned treatment works
Ninety-two and 99% wastewater treatment removal efficiency applied to P95 and P50 POTW scenarios respectively, based on site-specific information.

Given the greater magnitude and nationwide prevalence, concentration results from combined down-the-drain releases were carried forward for further assessment.

#### 1.4.3.2 Land Pathway

As discussed in Section 1.3.2, soils contain HHCB following land application of biosolids. Soil-dwelling organisms and plants may consequently be exposed; soil-dwelling organisms can bioaccumulate HHCB (Kinney et al., 2006) whereas plants show low bioaccumulation potential. A screening-level equation from the European Chemicals Bureau Technical Guidance Document (ECB, 2003) was utilized to estimate soil concentrations from a range of potential biosolid concentrations based on monitored concentrations. The maximum monitored biosolid concentration of 554,000 µg/kg (Kinney et al., 2006) was utilized to estimate a soil concentration of 1,629 µg/kg. Soil concentrations are highest immediately after land application and will decline over time due to biodegradation.

#### 1.4.3.3 Weight of Scientific Evidence Conclusions for Environmental Concentrations

EPA used both TRI-reported HHCB releases and probabilistic modeled release estimates. In 2023 TRI, all facilities reporting water releases of HHCB indicated off-site wastewater transfers. As discussed in Section 1.4.2.2, EPA has moderate confidence in the transferred volumes. These releases provide a snapshot of the waste transferred off-site in 2023 for wastewater treatment, but volumes may vary year-to-year as the demand of HHCB fluctuates. Although not incorporated into this assessment, a review of the 2024 TRI data indicates changes in the reported amounts and the identification of new reporters. Because effluent quantitates from off-site treatment facilities reported in TRI are less certain; a range of assumed wastewater-treatment removal efficiencies (50–92%) was applied in downstream concentration estimates.

EPA modeled down-the-drain HHCB releases to surface water using Monte Carlo methods that incorporate variability for commercial and consumer down-the-drain sources, estimating impacts to surface water and benthic sediments nationwide. The weight of scientific evidence shows HHCB enters wastewater via combined down-the-drain disposals, with resulting media concentrations strongly driven by POTW characteristics (contributing population, treatment level, and receiving water body). EPA has moderate confidence that this analysis identifies potential high-end (P95 POTW) receiving-water and sediment concentrations that can be used in human health and environmental risk assessment. Uncertainties such as prevalence of HHCB within product groups may bias the modeled concentrations high, while limiting business types (*e.g.,* casinos) may bias them low. Available monitoring generally aligns with the combined down-the-drain POTW scenarios, with most conditions yielding low ambient surface waters concentrations and elevated concentrations possible near POTW discharge points (up to 25.5 µg/L at the high-end of the monitoring data, with 25.4 µg/L representing the high-end of the modeled scenario).

# 2 ENVIRONMENTAL RISK ASSESSMENT

**Environmental Risk Assessment (Section 2):**
**Key Points**

***Aquatic Species***

- Ris quotient (RQ) values for aquatic organisms in surface water and sediment were derived for the highest-releasing COUs using the high-end (P95 POTW) aggregate commercial and consumer down-the-drain scenario. Additional RQs using the central-tendency (P50 POTW) scenario were calculated to further characterize risk and build confidence.
- For acute surface water exposures to aquatic vertebrates and invertebrates, RQ values did not exceed 1 across all release scenarios.
- For chronic surface water exposures to aquatic vertebrates and invertebrates, RQ values did not exceed 1 for the aggregate commercial and consumer down-the-drain P50 POTW scenario, and an RQ of 2.59 was calculated for the P95 POTW scenario.
- For sediment exposures, RQ did not exceed 1 for the aggregate commercial and consumer down-the-drain P50 POTW scenario, and an RQ of 3.2 was calculated for the P95 POTW scenario.
- Overall confidence in the protective nature of the surface water and sediment risk estimates is moderate-to-robust, as most scenarios with high-end inputs resulted in RQs less than 1. Risk estimates from the highest modeled water and sediment concentrations represent a high-end scenario of rarely occuring conditions and are expected to overestimate risk for most locations and conditions.
- The weight of evidence indicates that HHCB does not pose acute or chronic risk to aquatic and sediment-dwelling organisms in most U.S. water bodies with moderate-to-robust confidence.

***Terrestrial Species***

- Soil releases were not estimated; a screening assessment compared terrestrial invertebrates and plants hazard thresholds were compared to the maximum measured HHCB concentrations in biosolid-amended soil.
- For terrestrial invertebrates and plants, the hazard thresholds were not exceeded by any measured concentration; RQ values did not exceed 1.
- For mammals that consume aquatic organisms, dietary exposures based on measured and modeled HHCB concentrations in fish and aquatic organisms RQ values did not exceed 1.
- For mammals that consume earthworms, dietary exposures based on measured HHCB concentrations in earthworms RQ values did not exceed 1.
- The weight of evidence indicates that HHCB does not pose risk to terrestrial invertebrates, plants, or mammals, resulting in robust confidence in the protective nature of this screening assessment.

## 2.1 Summary of Environmental Hazards

Environmental hazard endpoints for HHCB were characterized using all reasonably available information identified through the systematic review process (U.S. EPA, 2026y). HHCB may be distributed as a mixture of diastereomers, and the combination of various substances may alter the toxicity profile (U.S. EPA, 2026s). Information on whether environmental hazard studies used isomer mixtures or neat compounds is not available.

### 2.1.1 Environmental Hazard Thresholds

Concentrations of concern (COCs) were derived for acute and chronic HHCB exposures in water and sediment ((U.S. EPA, 2026y); Table 2-1). EPA has robust confidence in the COCs based on the quality, consistency, strength and precision, and relevance of the underlying studies. Hazard thresholds were also derived for dietary HHCB exposure to terrestrial mammals and soil HHCB exposure to terrestrial invertebrates and plants. EPA has robust confidence in the quality, consistency, and strength and precision, of the underlying terrestrial invertebrate and plant studies; however, wildlife thresholds were extrapolated from laboratory rodent data using conservative assumptions of body weight, feeding rate, and assimilation efficiency resulting in moderate confidence in hazard threshold for wild mammal populations. The hazard thresholds were within the same order of magnitude as thresholds derived in previous HHCB environmental hazard assessments (OCSPP, 2014; ECB, 2008b).

**Table 2-1. HHCB Environmental Hazard Thresholds**

| Receptor Group | Exposure Duration and Organism Hazard | Hazard Threshold (COC or HV) | Assessment Medium | Citation (Study Quality) |
|---|---|---|---|---|
| Aquatic animals | Acute exposure resulting in aquatic vertebrate and invertebrate species mortality | 42.3 µg/L [a] | Water column | From SSD [b] |
| Aquatic vertebrates | Chronic exposure to aquatic vertebrate species (54% reduction in fish [(*Pimphales promelas*)] growth over 32 days) | 9.8 µg/L [c] | Water column | (Croudace et al., 1997) (High) |
| Sediment-dwelling invertebrates | Chronic exposure to sediment-dwelling animal species (49% reduction in *Lumbriculus variegatus* reproduction over 28 days) | 2.4 mg/kg dw [c] | Sediment | (IFF, Date Unknown) (High) |
| Terrestrial vertebrates | Chronic dietary exposure to terrestrial mammals (up to 7% lower pup weight) [d] | 35.0 mg/kg/day | Diet | (IFF, 2021) (Acceptable/Guideline) |
| Terrestrial invertebrates | Chronic exposure to soil invertebrates (30% lower earthworm [*Eisenia fetida*] reproduction over 28 days) | 38.7 mg/kg | Soil | (Chen et al., 2011) (High) |
| Terrestrial plants | Chronic exposure in soil to plants (50% lower rapeseed [*Brassica napus*] biomass over 21 days) | 3.55 mg/kg | Soil | (IFF, 2019) (High) |

COC = concentration of concern; HV = hazard value; SSD = species sensitivity distribution; dw = dry weight
[a] Represents the concentration expected to protect 95% of species. The measured LC50 of *Rana nigromaculata* (35 µg/L) was 5 times more sensitive to HHCB than the next most sensitive species (*Daphnia magna* LC50=194 µg/L).
[b] SSD-derived from LC50 values of 12 species that represent four different phyla (Annelida, Arthropoda, Chordata, and Mollusca) that inhabit both freshwater and marine environments.
[c] An assessment factor of 10 was applied to account for variation in species sensitivity and uncertainties in extrapolating from laboratory conditions to environmental concentrations and exposure durations (U.S. EPA, 2026y; Zeeman, 1995).
[d] Extended one generation dietary exposures to laboratory rats (Wistar strain) (IFF, 2021).

## 2.2 Conceptual Model

Conceptual models consider exposure pathways and routes along with hazards. Environmental exposure is expected primarily via the surface water pathway and soil from application of biosolids. HHCB enters ambient surface water via industrial releases and municipal wastewater discharges (POTWs) from down-the-drain disposals from products containing HHCB (Figure 2-1). Once in surface water, fish and other aquatic organisms may be exposed. HHCB is also expected to partition to sediment resulting in exposure to sediment-dwelling organisms. Ambient air releases from industrial activities are reported; however, releases are minimal and HHCB is not expected to persist (Section 1.3).

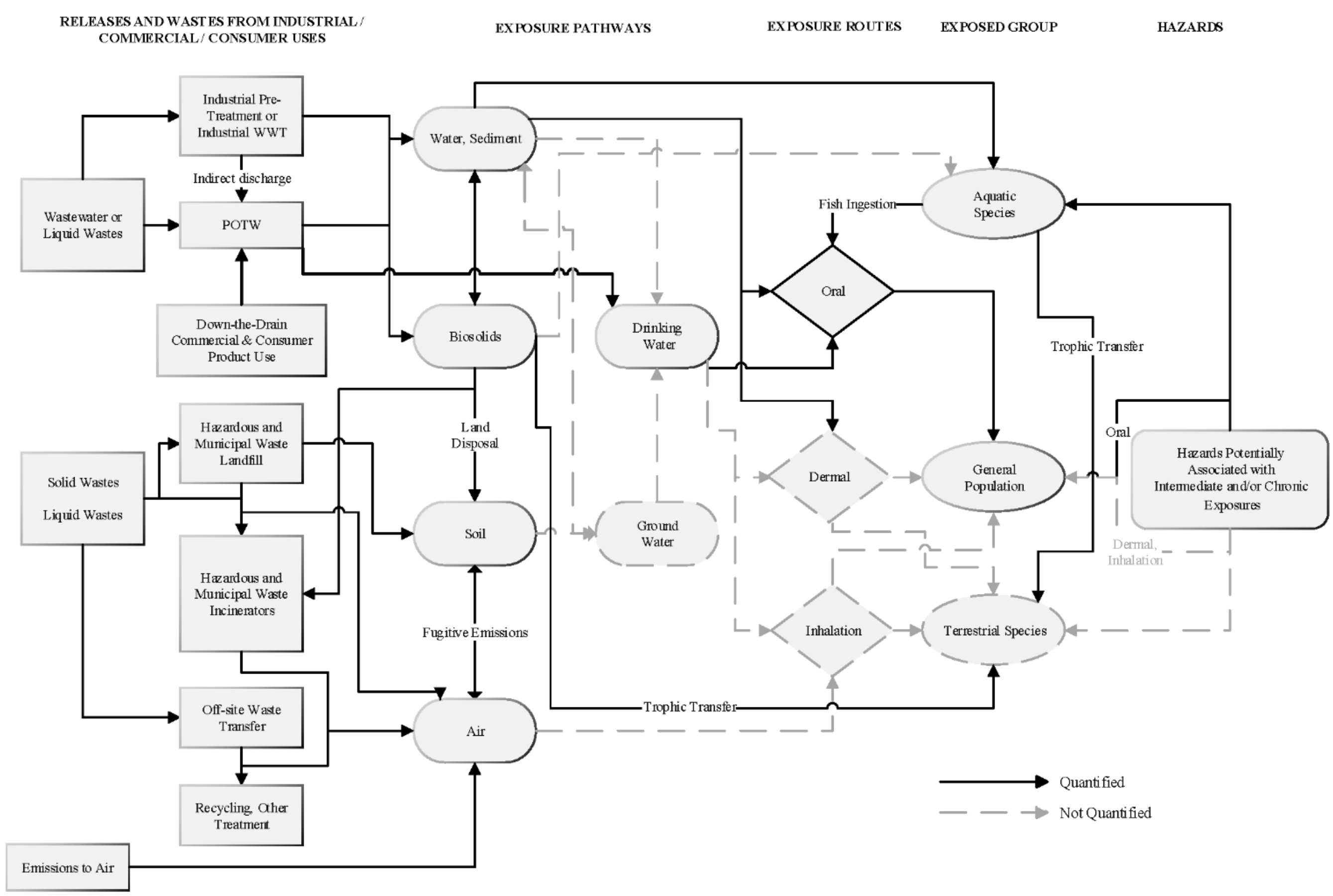


**Figure 2-1. Environmental Exposure and General Population Model of Scenarios Assessed**

## 2.3 Summary of Environmental Concentrations and Exposures

This evaluation characterizes the environmental releases (Section 1.4) and subsequent environmental exposure of HHCB in surface water, sediment, fish tissue, and soil from industrial releases and commercial and consumer down-the-drain releases (U.S. EPA, 2026s). A tiered approach was applied, combining screening-level methods with more refined analyses, based on the receptor assessed and the relevant exposure pathways.

### 2.3.1 Water Releases to Surface Water, Sediment, and Fish Tissue

Environmental exposure concentrations were estimated for industrial and commercial and consumer down-the-drain releases to surface water, sediment, and fish tissues (U.S. EPA, 2026s). Commercial and consumer down-the-drain receiving-water concentrations were modeled as combined releases to a single

POTW, using population-scaled average product use rates. POTW scenario characteristics were derived from CWNS data (U.S. EPA, 2025a) and reflect combination, treatment, and discharge from a single point source. Fish tissue concentrations and doses for fish ingestion by mammals were modeled using KABAM ($K_{OW}$ [based] Aquatic BioAccumulation Model) (U.S. EPA, 2009).

The highest potential HHCB exposures in surface water, sediment, and fish tissue occurred from combined commercial plus consumer down-the-drain release scenarios (Section 1.4.3.1; Table 1-15; Table 2-2). Confidence is moderate that the exposure assessment identified the potential high-end (P95 POTW) surface water and sediment concentrations due to uncertainties in business- and product-specific inputs into down-the-drain-models (Section 1.4.2.7). Confidence is robust that the fish bioaccumulation assessment identified the potential high-end fish tissue concentrations because multiple lines of evidence from modeling and measured data concur (Section 4.3.3.5.4 in (U.S. EPA, 2026s)).

**Table 2-2. HHCB Exposure Scenarios, Release Media, Route of Exposure, and Upper-Bound Environmental Exposure Concentrations Used in the Screening Risk Assessment**

| Screening Exposure Scenario | Release Medium | Pathway of Exposure | Upper Bound Estimated HHCB Concentration[a] |
|---|---|---|---|
| Combined Commercial Plus Consumer Down-the-Drain (P95 POTW) | Water | Surface water | 25.4 µg/L |
| | | Sediment | 7,741 µg/kg |
| | | Fish[b] | 6,071 µg/kg |
| N/A | Biosolids | Soil[c] | 1,629 µg/kg |
| | | Earthworm[d] | 58,644 µg/kg |

[a] The highest exposure concentrations from industrial release scenarios (0.57 µg/L surface water, 171 µg/kg sediment, and 902 µg/kg) were all less than these upper-bound concentrations used for screening (U.S. EPA, 2026s).
[b] HHCB in large fish (1.0 kg) estimated using KABAM with high-end surface water inputs and calculated within-fish metabolic transformation (U.S. EPA, 2026s).
[c] Highest soil concentration modeled from highest reported biosolid concentration 554,00 µg/kg (U.S. EPA, 2026s; Kinney et al., 2006).
[d] Highest earthworm concentration estimated using highest modeled soil concentration and highest reported earthworm bioaccumulation factor (36; (U.S. EPA, 2026s)).
Data summarized from U.S. EPA (2026s).

### 2.3.2 Biosolid Land Application to Soil and Earthworms

Land pathway exposures were evaluated using measured soil concentrations. Confidence in the absolute soil concentration is moderate because of uncertainties apportioning soil exposures to TSCA COUs vs. non-TSCA COUs and biosolid application rate, frequency, depth, and timing. Soil exposure to terrestrial organisms and earthworm uptake were modeled from the highest measured biosolids concentration and are expected to be low (Section 1.4.3.2; Table 2-1). Confidence in the absolute modeled soil concentration is moderate due to uncertainties in biosolid application and soil parameters, but confidence is robust that it represents an upper bound for screening risk (Section 4.3.2.3 in (U.S. EPA, 2026s)).

Because earthworm bioaccumulation depends on soil concentrations and a high-end bioaccumulation factor, there is robust confidence that the estimated upper bound is protective across scenarios with lower soil HHCB and lower earthworm BAF, whereas confidence in the absolute tissue concentration is moderate (Section 4.3.3.5.6 in (U.S. EPA, 2026s)).

## 2.4 Environmental Risk Characterization

Potential environmental risk was characterized by evaluating whether potential HHCB releases from TSCA COUs (Table 1-1) may produce exposures (U.S. EPA, 2026s) that exceed hazard thresholds linked to population-level effects in aquatic or terrestrial organisms (U.S. EPA, 2026y). Guided by the aforementioned conceptual exposure model (Section 2.2; Figure 2-1) the assessment focuses on water releases—primarily combined, community-level discharges from industrial, residential, and commercial product use (*e.g.,* laundry detergents, dishwashing detergents, and surface cleaners) that result in exposure to organisms in aquatic (water column and sediment) and soil environments (via biosolids application).

### 2.4.1 Risk Assessment Approach

In evaluating the HHCB environmental risk in surface water and sediments, a tiered screening analysis was used using upper bound measured and modeled exposure estimates (Section 3.3.1.2 and U.S. EPA (2026s). Environmental risk in soil via biosolids was also assessed in a screening analysis using upper bound measured soil concentrations not apportioned to TSCA COUs and non-TSCA COUs (Section 3.3.1.3 and U.S. EPA (2026s). Hazard threshold concentrations for the derivation of risk quotients used a weight of scientific evidence approach that included species across broad taxonomic groups to ensure the protection of the most sensitive species (U.S. EPA, 2026y).

Environmental risk was characterized by calculating risk quotients (RQs) (U.S. EPA, 1998; Barnthouse et al., 1982) from exposure concentrations (Table 2-2) and hazard thresholds (Table 2-1). The RQ is defined in Equation  below:

**Equation 2-1. Calculating the Risk Quotient**

$$RQ = \frac{Environmental\ Exposure\ Concentration}{Hazard\ Threshold}$$

The benchmark value for RQs in this environmental risk characterization was 1. If the RQ was above 1, the exposure was greater than the COC or hazard threshold concentration, providing evidence of potential adverse effects on populations of animals or plants. If the RQ was below 1, the exposure was less than the hazard concentration. An RQ equal to 1 indicates that the exposure is the same as the concentration that caused effects. Because risk is influenced by many factors together with the RQ (*e.g.,* variability, exposure duration, species sensitivity, uncertainty, etc.), additional evidence was considered when RQ values were above the benchmark. Variability in modeled and measured concentrations, exposure durations, and species sensitivities were considered to further characterize risk using the weight of available evidence.

Overall confidence in the risk assessment integrated lines of evidence from both exposures and hazards. Because monitored data apportioned to TSCA COUs and non-TSCA COUs were not reasonably available, exposure concentrations were modeled for COU-specific conditions using high-end inputs and conservative assumptions. This approach supports higher confidence in conclusions of no risk when RQs are less than 1. When RQs are greater than 1 in screening scenarios, the risk characterization was refined using additional lines of evidence, including comparisons to measured HHCB concentrations.

RQ values were derived for surface water and sediment exposure to aquatic organisms from the highest releasing COUs using the high-end (P95 POTW) of the combined commercial plus consumer down-the-drain releases (Table 2-3). Additional RQ values were derived from the central tendency (P50 POTW) of combined commercial plus consumer down-the-drain concentrations to further characterize and provide confidence in risk estimates. Industrial release scenarios were assessed but not reported here because the exposure concentrations from down-the-drain releases were greater than the highest industrial release scenario (U.S. EPA, 2026s).

In surface water and sediment scenarios, HHCB risk was assessed at the immediate WWT/POTW outflow, assuming substantial removal (92–99%; see Section 1.4.3.1 of this draft risk evaluation and Section 2.4.6 in U.S. EPA (2026s)). Given dilution and propensity of HHCB to bind to sediment (Section 2.4 in U.S. EPA (2026s)), concentrations are expected to decline downstream, so near-outfall risk estimates are protective of other locations. Additionally, most organisms, including fish, are transient so outfall concentrations are likely to overestimate actual exposures. The magnitude of overestimation is uncertain and depends on species-specific movement ranges and distance from the outfall. For down-the-drain release scenarios, continuous POTW releases were assumed and expected; consequently, any exceedance would persist and continuously exceed the relevant hazard threshold.

Wildlife exposure to HHCB was evaluated via two pathways: (1) direct soil exposure for terrestrial invertebrates and plants, and (2) modeled dietary exposure to terrestrial mammals through bioaccumulation and trophic transfer (Table 2-3). Risk from dietary exposure via fish ingestion was assessed using fish concentrations modeled with the KABAM food web model ($K_{OW}$ (based) Aquatic Bioaccumulation Model version 1.0 (U.S. EPA, 2026s, 2009).

**Table 2-3. Relevant Exposure Pathway to Organisms and Corresponding Risk Assessment for the HHCB Environmental Risk Characterization**

| Exposure Pathway | Exposure Duration and Organism Hazard | Risk Assessment |
|---|---|---|
| Surface water | Acute exposure resulting in aquatic vertebrate and invertebrate species mortality | RQ <1 in all scenarios with measured and modeled water concentrations |
| | Chronic exposure to aquatic vertebrate species (reduced fish [*(Pimphales promelas)*] reproduction over 32 days) | RQ <1 in all but the high-end measured and combined modeled commercial plus consumer down-the-drain water concentrations[a] |
| Sediment | Chronic exposure to sediment-dwelling animal species (reduced reproduction of *Lumbriculus variegatus* reproduction over 28 days) | RQ <1 in all but the high-end measured and combined modeled commercial plus consumer down-the-drain water concentrations[a] |
| Air | No evidence of adverse effects on wild animal populations | Qualitatively considered as no risk because of no evidence of hazard; no RQs calculated |
| Biosolids to soil | Chronic exposure to soil invertebrates (reduced earthworm [*Eisenia fetida*] reproduction over 28 days) and plants (reduced rapeseed [*Brassica napus*] biomass over 21 days) | RQ <1 in screening assessment with highest measured biosolid and soil concentrations |
| Trophic transfer from water | Chronic dietary exposure to terrestrial mammals (reduced mammal reproduction over 2 generations) | RQ <1 in all but the high-end measured and combined modeled commercial plus consumer down-the-drain water concentrations |
| Trophic transfer from soil | Chronic dietary exposure to terrestrial mammals (reduced mammal reproduction over 2 generations) | RQ <1 in all scenarios with upper bound earthworm BAF = 36 |
| BAF = bioaccumulation factor; COU = condition of use; RQ = risk quotient | | |

| Exposure Pathway | Exposure Duration and Organism Hazard | Risk Assessment |
|---|---|---|
| [a] EPA has moderate-to-robust confidence in scenarios with conservative and screening assumptions resulting in RQs <1. | | |

### 2.4.2 Risk Estimates for Aquatic Species

Risk to aquatic organisms was characterized by comparing COCs for aquatic organisms (U.S. EPA, 2026y) to the highest two modeled surface water and sediment concentrations from generic commercial and consumer down-the-drain water scenarios and combined releases (U.S. EPA, 2026s).

- The acute COC for aquatic animals of 42.3 µg/L was derived using a species sensitivity distribution (SSD) of LC50 values (concentrations of HHCB which are lethal to 50% of test organisms) from studies of fish and invertebrate mortality over acute exposure durations (48- to 96-hour) (U.S. EPA, 2026y).
- The chronic COC for aquatic vertebrates of 9.8 µg/L was derived from a 32-day study of the fathead minnow (*Pimephales promelas*) resulting in 78% lower survival, 20% reduction in standard body length, 54% reduction in weight, and increased incidence of erratic swimming behavior in treatments (U.S. EPA, 2026y).
- The COC for sediment-dwelling animals of 2.4 mg/kg dw was derived from 28-day sediment exposure to the worm *Lumbriculus variegatus* that resulted in 49% reduction in offspring production (U.S. EPA, 2026y).

For context, COCs were also compared to monitored HHCB concentrations reported from U.S. water bodies but were not known to be associated with specific TSCA COUs.

#### 2.4.2.1 Risk Estimates for Surface Water

***Acute Exposures***

The acute COC for aquatic animals (42.3 µg/L) (U.S. EPA, 2026y) was not exceeded by any modeled or measured HHCB concentrations (U.S. EPA, 2026s) resulting in all RQ values less than the benchmark of 1 for risk estimates of acute HHCB exposures in surface water.

This screening-level assessment used the highest modeled exposure concentration across all assessed scenarios and COUs. The estimate is an combination of commercial and consumer down-the-drain releases at the high end of the modeled POTW distribution in that 95% of POTWs are expected to release lower concentrations. Additionally, this scenario represents historical low-flow (7Q10) conditions that resulted in the high-end concentration assumed to occur at the immediate POTW outflow. Given dilution and the propensity of HHCB to bind to sediment (see Section 2.4 in U.S. EPA (2026s)), concentrations are expected to decline downstream. Therefore, near-outfall risk estimates from this high-end scenario are protective of other locations.

The acute COC is also protective in representing the concentration that protects 95% of species and was derived using hazard data across vertebrate and vertebrate species in freshwater and marine ecosystems (U.S. EPA, 2026y).

Data in the Water Quality Portal (WQP; (U.S. EPA, 2026s)) provide broad context and add confidence that this risk estimate is protective of other locations and scenarios. The highest measured values from the WQP database (25.5 µg/L; (U.S. EPA, 2026s)) does not exceed the acute exposure COC, but is comparable to the highest modeled concentration used in this assessment. Most other values from the WQP were at least an order of magnitude lower than the acute COC. These data are derived from numerous organizations with multiple sampling objectives that are not linked to the COUs in this assessment. In other words, the concentrations represent all potential uses of HHCB, including TSCA COUs and non-TSCA uses, making the WQP data less reliable and less relevant.

EPA has robust confidence in this risk characterization because of robust confidence in the acute aquatic COC (U.S. EPA, 2026y) and moderate confidence that the high-end (P95 POTW) receiving-water concentration represents an upper bound for this screening assessment (Section 1.4.3.1). Modeled exposure concentrations from all other scenarios, including those that used facility-specific TRI data (U.S. EPA, 2026s) were lower than the high-end (P95 POTW) scenario, resulting in robust confidence that this risk characterization is protective.

***Chronic Exposures***

Modeled and measured concentrations of HHCB in surface water indicate that RQ values potentially exceeded the benchmark for chronic exposures to aquatic vertebrates but were limited to higher-end exposure concentrations that represent combined exposures from TSCA COUs and other uses.

The highest modeled surface-water concentration resulted from the P95 POTW scenario (25.4 µg/L), representing medium-sized contributing populations and slow flow (7Q10) in small water bodies (U.S. EPA, 2026s). This yielded a chronic RQ of 2.59. The exposure estimate is intentionally conservative: It combines commercial and consumer down-the-drain releases that are overestimated for high-end POTWs (with <5% of POTWs expected to have higher concentrations), uses the highest product concentrations, the lower bound of wastewater treatment removal (92%), and applies a worst-case 7Q10 low-flow (17,300 $m^3$/day) condition. Applying the less conservative harmonic mean flow (20,700 $m^3$/day) for this scenario's location resulted in a surface water concentration of 21.1 µg/L and a chronic RQ of 2.15. However, this scenario with 99% wastewater treatment removal efficiency resulted in a surface water concentration of 2.35 µg/L and a chronic RQ of 0.24. Additionally, fish are unlikely to remain at effluent outfalls; and movement within and among habitats reduces sustained exposure. This scenario represents the highest modeled concentration across all assessed scenarios and COUs, and measured concentrations are much lower, reinforcing confidence that these exposure estimates are high end. Consequently, actual exposures are likely lower.

The P50 POTW scenario produced an exposure estimate of 1.11 µg/L, resulting in an RQ of 0.11. This scenario reflects releases with high-end contributing populations and slow flow (7Q10; 1,260,000 $m^3$/day) in medium-sized water bodies (U.S. EPA, 2026s), but represents a more likely exposure condition across the landscape while remaining conservative. For example, it still applies the 7Q10 flow metric and assumes fish remain near effluent outfalls and experience constant exposure. It was the second-highest modeled exposure concentration across scenarios.

Collectively, these RQs indicate that most risk estimates are below the benchmark of 1, consistent with a low potential for chronic risk. The highest modeled concentration reflects a high-end, rarely occurring scenario, and is expected to overestimate risk for most locations and conditions due to compounding conservatisms. EPA has less confidence that this high-end estimate reflects a typical scenario, as it is based on historical 7Q10 low-flow conditions (seven-day, ten-year low flow), which could indicate potential for chronic population-level effects (*e.g.,* reduced reproduction) under rare low-flow/high-exposure conditions. More realistic scenarios that combine and account for variable wastewater treatment removal efficiencies, water concentrations driven by variable flow rates (despite constant POTW releases) and fish behavior (*e.g.,* variable home ranges and active contaminant avoidance (Ehiguese et al., 2019)) would reduce chronic HHCB exposure below thresholds for adverse population-level effects.

Data in the WQP (U.S. EPA, 2026s) provide broad context for assessing whether modeled water concentrations are realistic. The highest two measured values from the WQP database (25.5 µg/L; (U.S. EPA, 2026s)) exceed the chronic fish exposure COC. However, the next highest concentration (4.6 µg/L; (U.S. EPA, 2026s)) and the remaining values were lower than this COC. These data are derived from numerous organizations with multiple sampling objectives that are not linked to the COUs in this assessment. In other words, the concentrations represent all potential uses of HHCB including TSCA COUs and non-TSCA uses, making the WQP data less reliable and less relevant.

EPA has robust confidence in this risk characterization because of robust confidence in the COC (U.S. EPA, 2026y) and moderate confidence that the high-end (P95 POTW) receiving-sediment concentration represents an upper bound for this screening assessment (Section 1.4.3.1). Modeled exposure concentrations from all other scenarios, including those that used facility-specific TRI data (U.S. EPA, 2026s), were lower than the high-end (P95 POTW) scenario, resulting in robust confidence that this risk characterization is likely to overestimate risk.

#### 2.4.2.2 Risk Estimates for Sediment

Modeled and measured concentrations of HHCB in the sediment of U.S. water bodies indicate that RQ values exceed the benchmark of 1 are possible but limited to higher-end exposure concentrations.

The COC of sediment-dwelling animal exposure (2,400 µg/kg HHCB) (U.S. EPA, 2026y) was less than the exposure concentration from down-the-drain modeling in the P95 POTW scenario (7,741 µg/kg) resulting in a RQ of 3.2. Similar to the highest surface water estimate (Section 2.4.2.1), the highest sediment exposure estimate is intentionally conservative: It combines commercial and consumer down-the-drain releases that are overestimated for high-end POTWs (with fewer than 5% of POTWs expected to have higher concentrations), uses the highest product concentrations, the lower bound of wastewater treatment removal (92%), and applies a worst-case 7Q10 low-flow (17,300 $m^3$/day) condition. Applying the less conservative harmonic mean flow (20,700 $m^3$/day) for this scenario's location resulted in a sediment concentration of 4,790 µg/kg and an RQ of 2.00. However, this scenario with 99% wastewater treatment removal efficiency resulted in a sediment concentration of 717 µg/kg and a sediment-dwelling animal RQ of 0.29. This scenario represents the highest modeled concentration across all assessed scenarios and COUs and measured concentrations are much lower, reinforcing confidence that these exposure estimates are high-end. Consequently, actual exposures are likely lower.

The COC for adverse population-level effects on sediment-dwelling animals represents a reduction in reproductive output in a controlled laboratory setting and was derived using a protective assessment factor of 10 to account for variation in species sensitivity and uncertainties in extrapolating from laboratory conditions to environmental concentrations and exposure durations (U.S. EPA, 2026y). In a field setting, sediment-dwelling animals such as amphipods, worms, and insect larvae are mobile within sediment patches, exhibit larger scale drift dispersal due to disturbances and are unlikely to remain at effluent outfalls, and movement within and among habitats reduces sustained exposure. Finally, this scenario also makes the conservative assumption that 100% of the HHCB sorbed to sediment or in the porewater is bioavailable. Thus, the sediment-dwelling animal COC is also intentionally conservative.

The COC of sediment-dwelling animal exposure (2,400 µg/kg HHCB) (U.S. EPA, 2026y) was above the exposure estimate from down-the-drain modeling in the P50 POTW scenario (295 µg/kg) resulting in a RQ of 0.12 and represents releases with high-end contributing populations and slow flow in medium-sized water bodies (7Q10). This exposure scenario represented the second-highest modeled exposure concentration, including those that used facility-specific TRI data (U.S. EPA, 2026s) that were lower than this scenario.

Collectively, these RQ values indicate that most risk estimates, except for the most conservative scenario, were below the benchmark of 1. This indicates a low potential for risk to sediment-dwelling animals. The highest modeled concentration represents a high-end scenario of rarely occuring conditions and is expected to overestimate risk for most locations and conditions due to the compounding conservatives. Specifically, EPA has less confidence that this high-end risk estimate reflects a representative scenario, as it models exposure conditions at historical 7Q10 low-flow (7-day, 10-year low flow), indicating potential for chronic population-level effects (*e.g.,* reduced reproduction) under rare low-flow/high-exposure conditions. More realistic scenarios that combine and account for variable wastewater treatment removal efficiencies, variable sediment concentrations due to variable flow rates (despite constant releases from POTWs) and variable animal behavior due to variable home ranges and active contaminant avoidance behaviors (Ehiguese et al., 2019) would reduce sediment HHCB exposure below the threshold that adversely affects animal populations.

EPA has robust confidence that the screening-level COC for the sediment-dwelling animals represents a conservative hazard benchmark that accounts for variation in species sensitivity and uncertainties in extrapolating from laboratory conditions to environmental concentrations and exposure durations (U.S. EPA, 2026y). The Agency has moderate confidence in the modeled sediment exposure estimates (U.S. EPA, 2026s) leading to these risk estimates. Thus, EPA has robust confidence in these risk estimates because RQ values were less than the benchmark of 1 in most down-the-drain release scenarios, resulting in no expected adverse effects on populations of sediment-dwelling animals.

Data in the WQP (U.S. EPA, 2026s) can provide the broad context about whether modeled sediment concentrations represent realistic concentrations. The highest measured value from the WQP database (6,860 μg/kg; (U.S. EPA, 2026s)) exceeded the sediment-dwelling animal exposure COC. However, the remaining measured values in the WQP database were mostly below 1,000 μg/kg and lower than the COC. These data were derived from numerous organizations with multiple sampling objectives that are not linked to the COUs in this assessment. In other words, data from the WQP represent all potential uses of HHCB including TSCA COUs and non-TSCA uses, making data from WQP less reliable and less relevant than concentrations modeled from facility-specific TRI data that are linked to COUs.

#### 2.4.2.3 Weight of Scientific Evidence of Risk Estimates for Aquatic Species

The weight of evidence indicates that HHCB does not pose acute or chronic risk to aquatic organisms in the water column or sediment in most U.S. water bodies, with moderate-to-robust confidence. A subset of localities with elevated HHCB—including sites conservatively modeled using P95 combined down-the-drain concentrations—may exceed the COC, indicating potential for adverse effects in chronically exposed fish and sediment-dwelling populations. However, EPA finds these scenarios to be to be rare, high-end exceptions rather than representative of most U.S. water bodies. Confidence in these potential effects is lower due to the compounding conservatism used in this screening assessment.

A strength of this risk characterization is the context of multiple data sources from measured exposure concentrations (see Sections 4.3.1.1.1 and 4.3.1.1.2 in U.S. EPA (2026s)), modeled exposure concentrations from TRI-reported release data (Section 4.3.1.2.1 in U.S. EPA (2026s)), and modeled down-the-drain release data (Section 1.4.3.1), resulting in more confidence in exposure estimates. Additional confidence comes from conservative and protective COCs that delineate adverse effects to populations of aquatic species (Section 4.2.1 and (U.S. EPA, 2026y)).

EPA has robust confidence in the COCs (U.S. EPA, 2026y) and moderate confidence in the modeled surface water and sediment exposure estimates (U.S. EPA, 2026s) leading to these risk estimates.

First, EPA found limited evidence of HHCB water concentrations in the United States exceeding the COC of 9.8 µg/L for chronic aquatic vertebrates. The high-end P95 POTW model estimate was 25.4 µg/L, which is comparable to the maximum measured concentration of 25.5 µg/L but it exceeds the median and 95th percentile measured concentration (0.06 and 1.65 µg/L respectively from 662 reported values) by over an order of magnitude (U.S. EPA, 2026s). Similarly, EPA found limited evidence of HHCB sediment concentrations exceeding the COC of 2,400 µg/kg, yet the high-end P95 POTW model estimates up to 7,741 µg/kg in sediment, which exceeds the maximum measured concentration of 6,860 µg/kg and exceeds the median and 95th percentile measured concentration (37 and 468.2 µg/kg respectively from 60 reported values) by over an order of magnitude (U.S. EPA, 2026s). Moreover, these measured concentrations represent unknown relationships to TSCA COUs and non-TSCA COUs. Data in the WQP (U.S. EPA, 2026s) can provide the broad context about whether modeled sediment concentrations represent realistic concentrations. These data were derived from numerous organizations with multiple sampling objectives that are not linked to the COUs in this assessment. In other words, they represent all potential uses of HHCB including TSCA COUs and non-TSCA uses, making data from WQP less reliable and less relevant than concentrations modeled from facility-specific TRI data that are linked to COUs.

Second, these screening-level risk assessments of chronic fish and sediment-dwelling animal exposure incorporated multiple conservatisms. Refining the assessment by considering fewer conservative inputs and assumptions leads to risk estimates less than the benchmark of 1 across all scenarios.

This screening assessment included several conservative assumptions that resulted in compounded conservatism and likely leads to an overestimate of the RQs:

- down-the-drain modeling assumes 100% of product HHCB reaches a wastewater treatment facility with no retention during use or sorption in drainpipes (U.S. EPA, 2026s);
- receiving-water models use historically low flow rates, whereas typical flows are higher for most of the year and would lower HHCB concentrations;
- fish and sediment-dwelling animals are assumed to experience continuous exposure at the estimated concentrations without accounting for environmental variability or animal behavior; and
- hazard thresholds are conservative, extrapolated from controlled laboratory studies.

Despite the conservatisms, most RQs from modeled down-the-drain scenarios are less than the benchmark of 1 and all TRI-based industrial water concentrations (U.S. EPA, 2026s) result in RQs less than 1. Thus, EPA has robust confidence in the protective nature of the national screening assessment of water column and sediment exposures to aquatic organisms, while confidence in taxa- or location-specific chronic risk prediction is low.

### 2.4.3 Risk Estimates for Terrestrial Species

A screening-level assessment that used upper bound exposure concentrations in soil and animals via bioaccumulation was used to estimate risk of HHCB to terrestrial invertebrates, plants, and mammals. The maximum reported HHCB concentration in biosolids was used as the upper bound to screen soil exposures because of a lack of available data related to the TSCA COUs described in this assessment. The upper bound soil concentration used in this screening assessment was 1,629 µg/kg (U.S. EPA, 2026s). Animals obtain HHCB through their diet, meaning measurable trophic transfer of HHCB occurs from prey to predator (U.S. EPA, 2026s; Kinney et al., 2006; Kannan et al., 2005). Therefore, the highest measured concentration in fish from U.S. water bodies and the upper bound modeled concentrations in fish and other aquatic animals were used in a screening risk assessment. The upper bound fish concentration used in this screening assessment was 6,071 µg/kg wet weight (U.S. EPA, 2026s).

A dietary hazard threshold was derived from laboratory rodent experiments and extrapolated to representative wild mammals (U.S. EPA, 2026y). For the biosolids to soil pathway, the northern short-tailed shrew (*Blarina brevicauda*) is a semifossorial carnivore that represents earthworm-eating mammals in this assessment. The upper bound earthworm concentration used in this screening assessment was 58,644 µg/kg (U.S. EPA, 2026s).

This section includes an assessment of the biosolid to soil pathway that leads to HHCB in earthworms that represent exposure concentrations and potential risk to earthworm-eating shrews. This section also includes an assessment of the water pathway that leads to HHCB in aquatic animal tissues that represent exposure concentrations and potential risk to mammals that consume aquatic animals. For the aquatic to terrestrial mammal pathway, multiple mammal species were considered:

- The hazard threshold for terrestrial invertebrates of 38.7 mg/kg HHCB was derived using a 14-day study of earthworms (*Eisenia fetida*) that resulted in 30% fewer cocoons (U.S. EPA, 2026y; Chen et al., 2011).
- The hazard threshold for terrestrial plants of 3.55 mg/kg HHCB was derived from using a study of the rapeseed, *Brassica napus*, that resulted in 50% lower growth biomass after 21-days of soil exposure (U.S. EPA, 2026y; IFF, 2019).
- The terrestrial mammal hazard threshold of 35 mg/kg-bw/day HHCB was derived from studies of laboratory rodents used for human health hazards of dietary exposure. This threshold represents a 6 to 15% lower pup body weight in from an extended one-generation laboratory rat experiment (U.S. EPA, 2026y; IFF, 2021).

#### 2.4.3.1 Risk Estimates for Invertebrates via Soil Exposure

The hazard threshold of HHCB in soil to terrestrial invertebrates (38,700 µg/kg) (U.S. EPA, 2026y) was not exceeded by the upper-bound measured HHCB concentration applied as biosolids to soil (1,629 µg/kg in soil derived from 554,000 µg/kg HHCB in biosolids (Section 1.4.3.2) resulting in an RQ of 0.04, which is less than the benchmark of 1.

The hazard threshold for terrestrial invertebrates of 38.7 mg/kg HHCB was derived using a 14-day study of earthworms (*Eisenia fetida*) that resulted in 30% fewer cocoons (U.S. EPA, 2026y; Chen et al., 2011). This threshold represents the lowest hazard value three study species and the potential adverse population-level effects in a laboratory setting. In a field setting, animals are mobile and are unlikely to remain at localities with the highest concentrations; movement within and among habitats reduces sustained exposure. Finally, this scenario also makes the conservative assumption that 100% of the HHCB sorbed to soil or in the soil porewater is bioavailable. Thus, the terrestrial invertebrate hazard threshold is intentionally conservative.

The maximum reported HHCB concentration in biosolids was used as the upper bound to screen soil exposures because of a lack of available data related to the TSCA COUs described in this assessment. The upper bound soil concentration used in this screening assessment was 1,629 µg/kg (U.S. EPA, 2026s).

Confidence is robust in the protective nature of the risk estimates to terrestrial invertebrates. EPA conducted a screening assessment that compared the highest estimates of soil concentrations from biosolid land applications to a protective hazard threshold that was derived from multiple earthworm studies. While COU-specific releases were not estimated, the screening assessment with upper-bound values using monitoring data resulted in no risk estimates exceeding the benchmark of 1.

#### 2.4.3.2 Risk Estimates for Terrestrial Plants via Soil Exposure

The hazard threshold of HHCB in soil to plants (3,550 µg/kg) (U.S. EPA, 2026y) was not exceeded by the upper bound measured HHCB concentration applied as biosolids to soil (1,629 µg/kg in soil derived from 554,000 µg/kg HHCB in biosolids see Section 1.4.3.2) resulting in an RQ of 0.46, which is less than the benchmark of 1.

The hazard threshold for terrestrial plants of 3.55 mg/kg HHCB was derived from using a study of the rapeseed, *Brassica napus*, that resulted in 50% lower growth biomass after 21-days of soil exposure (U.S. EPA, 2026y; IFF, 2019). This threshold represents the lowest hazard value from 16 study species and the potential adverse population-level effects in greenhouse settings. Finally, this scenario also makes the conservative assumption that 100% of the HHCB sorbed to soil or in the soil porewater is bioavailable to plants. Thus, the plant hazard threshold is intentionally conservative.

The maximum reported HHCB concentration in biosolids was used as the upper bound to screen soil exposures because of a lack of available data related to the TSCA COUs described in this assessment. The upper bound soil concentration used in this screening assessment was 1,629 µg/kg (U.S. EPA, 2026s).

Confidence is robust in the protective nature of the risk estimates to terrestrial plants. EPA conducted a screening assessment that compared the highest estimates of soil concentrations from biosolid land applications to a protective hazard threshold that was derived from multiple plant studies. While COU-specific releases were not estimated, the screening assessment with upper bound values using monitoring data resulted in no risk estimates exceeding the benchmark of 1.

#### 2.4.3.3 Risk Estimates for Terrestrial Mammals via Trophic Transfer

The terrestrial mammal hazard threshold of 35,000 µg/kg-bw/day HHCB was derived from studies of laboratory rodents used for human health hazards of dietary exposure (U.S. EPA, 2026y; IFF, 2021). This hazard threshold was used to calculate RQ values in a screening risk assessment for fish-eating mammals using the highest measured concentrations of HHCB in fish collected in the United States and using high-end estimated water concentrations from industrial release models and down-the-drain models.

##### 2.4.3.3.1 Risk Estimates to Fish-Eating Mammals Using KABAM

An OECD guideline BCF of 1,584 was selected as a representative BAF in fish, but the Agency also recognizes the extensive variation in bioaccumulation factors (Section 1.3.2 and (U.S. EPA, 2026s)). Therefore, the KABAM ($K_{OW}$ (based) Aquatic Bioaccumulation Model version 1.0 (U.S. EPA, 2009)) was used to estimate HHCB bioaccumulation in freshwater ecosystems and subsequent risk to mammals. The HHCB concentrations in animals at multiple trophic levels were derived using KABAM and upper bound modeled down-the-drain water column HHCB (25.4 µg/L from the P90 POTW scenario (U.S. EPA, 2026s)). The highest modeled concentration in large fish was 6,000 µg/kg in large fish of 1.0 kg (U.S. EPA, 2026s). The calculated RQ values were less than 1 for all mammal species in all exposure scenarios (Table 2-4).

**Table 2-4. Risk Quotients for Dietary Risk to Mammals from KABAM**

| Scenario | SWC (µg/L) [a] | Dose-Based Risk Quotients [f] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fog and Water Shrews (0.018 kg) | Rice Rat Star-Nosed Moles (0.085 kg) | Small Mink (0.45 kg) | Large Mink (1.8 kg) | Small River Otter (5 kg) | Large River Otter (15 kg) |
| Consumer Plus Commercial Combined DTD [b] (P95 POTW) | 25.4[c] | 0.16 | 0.15 | 0.08 | 0.08 | 0.09 | 0.07 |
| Consumer Plus Commercial Combined DTD [b] (P50 POTW) | 1.1 | 7.0E−03 | 6.0E−03 | 3.0E−03 | 4.0E−03 | 4.0E−03 | 3.0E−03 |
| Highest estimated water concentration from Industrial releases (Manufacturing) [d] | 0.57 | 4.0E−03 | 3.0E−03 | 2.0E−03 | 2.0E−03 | 2.0E−03 | 2.0E−03 |
| Highest monitored fish tissue (common carp, whole fish) [e] | N/A | N/A[g] | N/A[g] | 0.06 | 0.09 | 0.12 | 0.15 |

SWC = surface water concentration
[a] Surface water concentration of HHCB.
[b] DTD = down-the-drain.
[c] Highest SWC from monitored surface water = 25.5, effectively equal to the Consumer Plus Commercial Combined DTD (P95 POTW).
[d] Modeled release values estimated using 2023 TRI data.
[e] From (Ramirez et al., 2009).
[f] High-end body weights were used for shrews and moles while low-end and high-end body weights for large and small mink and otter from U.S. EPA (1993) and also used in KABAM (U.S. EPA, 2009).
[g] Shrews, rats, and moles consume aquatic invertebrates but not fish (U.S. EPA, 2026s).

The terrestrial mammal toxicity reference value (TRV) of 35 mg/kg-bw/day HHCB was derived from studies of laboratory rodents used for human health hazards of dietary exposure. This threshold represents a 6 to 15% lower pup body weight in from an extended one-generation laboratory rat experiment (U.S. EPA, 2026y; IFF, 2021). This threshold represents the lowest hazard value from five rodent studies and the potential adverse population-level effects in laboratory settings. Finally, this scenario also makes the conservative assumption that 100% of the HHCB in mammal food is bioavailable to mammals. Thus, the mammal hazard threshold is intentionally conservative.

The highest modeled surface water concentration (25.4 µg/L) that was used to model the highest concentration in fish (6,000 µg/kg) resulted from the P95 POTW scenario that represents medium-sized contributing populations and slow flow (7Q10) in small water bodies (U.S. EPA, 2026s). The exposure estimate is intentionally conservative: it combines commercial and consumer down-the-drain releases for high end POTWs (with <5% of POTWs expected to have higher concentrations), uses the highest product concentrations, and applies a worst-case, 7Q10 low-flow condition. Additionally, fish are unlikely to remain at effluent outfalls; movement within and among habitats reduces sustained exposure. This scenario represents the highest modeled concentration across all assessed scenarios and COUs, and measured concentrations are much lower, reinforcing confidence that these exposure estimates are high-end. Consequently, actual exposures and subsequent accumulation in fish are likely lower.

EPA has robust confidence in this risk characterization because of robust confidence in the COC (U.S. EPA, 2026y) and moderate confidence that the high-end (P95 POTW) receiving-water concentration represents an upper bound for this screening assessment (Section 1.4.3.1). Modeled exposure concentrations from all other scenarios, including those that used facility-specific TRI data (U.S. EPA, 2026s) and measured data from wild caught fish (Ramirez et al., 2009) were lower than the high-end (P95 POTW) scenario, resulting in robust confidence that this risk characterization is protective.

##### 2.4.3.3.2 Risk Estimates to Earthworm-Eating Shrews

HHCB may be present in soils due to land application of biosolids containing HHCB (U.S. EPA, 2026s) resulting in potential exposure to soil-dwelling organisms, including earthworms. Earthworms have been reported to bioaccumulate HHCB in tissues up to 3,340 µg/kg (Kinney et al., 2006).

Due to evidence of earthworm bioaccumulation and the hazard potential to worm-eating mammals via the biosolids to soil pathway, the predicted earthworm HHCB concentrations from the upper bound modeled soil HHCB concentration of 1,629 µg/kg HHCB was calculated as described in in the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s). The terrestrial mammal hazard threshold of 35,000 µg/kg-bw/day HHCB that was derived from studies of laboratory rodents used for human health hazards of dietary exposure (U.S. EPA, 2026y; IFF, 2021) was used to calculate RQ values in a screening assessment of risk to earthworm-eating mammals.

Using the upper-bound soil concentration of HHCB (1,629 µg/kg dry weight), dietary risk to a small worm-eating mammal (shrew) was screened under high-end and conservative assumptions. Earthworm concentrations were estimated using the highest field-derived bioaccumulation factor (BAF = 36) representing peak soil concentration shortly after biosolid additions (Kinney et al., 2012) providing an upper bound earthworm concentration of 58,644 µg/kg dry weight.

Assuming 100% earthworm diet and a food ingestion rate of 5% of body weight daily (default food ingestion rate across species; U.S. EPA, 1993, 3056849}), the modeled shrew dietary exposure dose was 5,300 µg/kg-bw/day. Dividing the estimated exposure by the mammalian dietary hazard threshold (35,000 µg/kg-bw/day) results in an RQ of 0.15 from upper-bound biosolid application and maximum dietary assumptions.

Confidence is robust that this risk estimate of HHCB dietary hazard to shrews through the biosolid, soil, and earthworm pathways is protective. Although the maximum measured value provides broad context on the realism of modeled soil concentrations, less weight is placed on these data because the data are from studies differing designs and are not apportioned to TSCA COUs. This estimate represents the short-term soil concentrations and short-term accumulation in earthworms after biosolid application to soils, after which concentrations decline at rates that depend on environmental conditions and biosolid re-application time intervals. HHCB half-life in soil is reported in one study as approximately 140 days (DiFrancesco et al., 2004), but Kinney (2006) reported over 90% lower HHCB in earthworms over 120 days. Overall, these concentrations represent upper bound soil and earthworm concentrations immediately after application making them upper bounds of possible values that represent chronic HHCB concentrations from COUs in U.S. soil that would adversely affect shrew populations through dietary exposure. However, confidence is robust in this screening assessment that used upper bound inputs and assumptions, resulting in no risk estimates exceeding the benchmark of 1.

#### 2.4.3.4 Weight of Scientific Evidence of Risk Estimates for Terrestrial Species

Confidence is robust in the protective nature of the risk estimates to terrestrial invertebrates and plants. EPA conducted a screening assessment that compared the highest estimates of soil concentrations from biosolid land applications to protective hazard thresholds that were derived from multiple earthworm and plant studies. While COU-specific releases were not estimated, the screening assessment with upper bound values using monitoring data resulted in no risk estimates exceeding the benchmark of 1.

Confidence is robust in the protective nature of the risk estimates to terrestrial mammals through the biosolids to shrew trophic transfer pathway using the reasonably available measured data in biosoilds and soil. No TSCA COU land releases were estimated. Thus, reported measured HHCB in biosolids and soil were used. The maximum concentration measured in biosolids resulted in RQ less than 1. This analysis is conservative as it does not account for HHCB biodegradation in soil and uses a shrew hazard threshold extrapolated from a laboratory rodent study, likely overestimating population-level effects.

Confidence is robust that the estimated concentrations of HHCB in fish represent an upper bound for EPA's screening assessment. However, there is less confidence that these upper-bound estimates are predictive and represent HHCB concentrations in fish tissue. Actual concentrations of HHCB in wild fish are lower than those derived using modeled surface water concentrations and modeled bioaccumulation from KABAM because real aquatic environments rarely meet the assumptions that underlie high-end and model inputs (Arnot and Gobas, 2006).

EPA has less confidence in the estimated high-end HHCB concentrations in fish tissues for two major reasons. First, there is no evidence that fish in the U.S. contain concentrations greater than 2,100 μg/kg ww. Second, bioaccumulation indices and models are not intended to be used to directly predict real world concentrations in wild fish but can be used as screening-level indicators and to make comparisons among chemicals (OECD, 2012; Arnot and Gobas, 2006). Screening level use of KABAM in estimating predicted fish tissue concentrations is meant to be conservative and protective. A refined or local assessment would use models of uptake, metabolism, diet, growth, and elimination and specific taxa- and location information in kinetic models for fish tissue predictions. These models would result in more realistic and lower HHCB concentrations in fish.

This screening risk assessment of fish ingestion by wildlife incorporated multiple levels of conservatism. First, in modeling down-the-drain scenarios of HHCB release, 100% of the HHCB in a consumer product is assumed to go down-the-drain and reaches a wastewater treatment facility without any retention during product usage or sorption of HHCB to organic matter in drainpipes that preceding wastewater treatment facilities. Second, model simulations used historically low stream flows; actual flows are typically faster for most of the year, which would reduce HHCB concentrations. Third, the KABAM screening assumes continuous exposure to the upper bound HHCB concentration and instantaneously steady state with the water concentration, without accounting for variability in environmental conditions or fish behavior. Finally, the hazard threshold value is conservative. It is extrapolated from a laboratory rodent study, assuming observed effects translate to adverse population-level effects, and presuming wild mammals only consume fish. Despite the compounded conservatism, the screening assessment resulted in all RQ values being less than the benchmark of 1. Confidence is robust in the protective nature of the national screening assessment of dietary risk to fish-ingesting wildlife, with less confidence in using the analysis in predicting more taxa-specific or location-specific conclusions.

## 2.5 Environmental Risk Conclusions, Overall Confidence, and Remaining Uncertainties

The weight of evidence indicates that HHCB does not pose acute or chronic risk to aquatic and sediment-dwelling organisms in most U.S. water bodies with moderate-to-robust confidence (Table 2-5). A subset of localities with elevated HHCB, including those containing high-end measured concentrations and P95 modeled down-the-drain concentrations, may have modeled concentrations of HHCB greater than the COC, indicating potential for adverse effects on chronically exposed fish and sediment-dwelling animal populations, but EPA has less confidence in these estimates compared to estimates from all other scenarios.

A strength of this risk characterization is the context of multiple data sources from measured values, modeled values from TRI-reported release data, and modeled down-the-drain values, which results in more confidence in the lower exposure estimates being representative of most COU-related risk estimates. Additional confidence comes from conservative and protective COCs that describe adverse effects to populations of aquatic species. Specifically, EPA's screening assessment with the protective and conservative COC for acute HHCB exposures resulted in no RQ values greater than the benchmark of 1. EPA has less confidence in the specific risk estimates from high-end modeled HHCB water and sediment concentrations because screening risk assessments of chronic fish and sediment-dwelling animal exposure EPA incorporated multiple levels of conservatism. Refining the assessments by considering less conservative and protective inputs and assumptions would logically lead to risk estimates less than the benchmark of 1 in all scenarios.

EPA has robust confidence in the protective nature of the risk estimates to terrestrial invertebrates and plants through comparisons with measured concentrations in soil and estimates of soil concentrations from biosolid applications to land. While EPA did not estimate COU-specific releases, the screening assessment resulted in no risk estimates exceeding the benchmark of 1.

EPA has robust confidence that the estimated concentrations of HHCB in fish represent high-end estimates for the screening assessment. The Agency has less confidence that these estimates represent HHCB concentrations in real fish tissue because no available evidence of fish in the United States having comparable fish tissue concentrations. Thus, EPA has robust confidence in the protective nature of the national screening assessment of dietary risk to fish-ingesting wildlife, but less confidence in using the analysis in predicting more taxa-specific or location-specific conclusions.

Environmentally relevant assessments have been published by EPA (OCSPP, 2014) and the ECB (ECB, 2008b). Environment and Climate Change Canada (ECCC) has designated HHCB as a priority for assessment under the Canadian Environmental Protection Act, 1999 (CEPA) because (1) an information gathering initiative in 2017 (ECCC, 2017), and (2) subsequent wastewater monitoring in Canada indicates that aquatic organisms may be exposed to HHCB through wastewater from both manufacturers and the use of products available to consumers (ECCC, 2024). The EPA TSCA Work Plan assessment reported low HHCB risk concerns to aquatic and sediment-dwelling organisms because exposure concentrations were one to two orders of magnitude below hazard COCs (OCSPP, 2014). Similarly, the ECB Risk Assessment Report concluded no need for further information and/or testing and no need for risk reduction measures beyond those already applied because all aquatic and sediment scenarios resulted in ratios of predicted environmental concentrations to predicted no-effect concentrations that were less than one (ECB, 2008b).

More recently, Gefell (2025) developed an extensive but nonregulatory fish ecological hazard assessment of contaminants of emerging concern including HHCB in the Great Lakes-Upper St. Lawrence River drainage. In this assessment, effect-specific ranges of screening values were compared to HHCB water concentrations measured across the Great Lakes basin. Gefell (2025) reported no occurrences where surface water exposures exceeded high screening values based on experimental lowest effect concentrations for mortality (74.4 µg/L), reproduction (3.26 µg/L), behavior (35 µg/L), development (53 µg/L), growth (74 µg/L), or physiological/metabolic (2.84 µg/L) effects. However, exposure concentrations above low screening values based on experimental no-effect concentrations occurred in 2% of mortality screens and 57% of reproduction screens, indicating that adverse effects are possible and prevalent for fish population-relevant effect categories such as mortality and reproduction. Overall, risk estimates for acute and chronic HHCB exposure to aquatic animals, including fish, in this assessment are consistent with this nonregulatory assessment of fish in surface waters of the Great Lakes basin.

The risk estimates in this draft assessment do not differ from previous assessments, providing additional confidence in the conclusion that HHCB does not pose acute or chronic risk to aquatic or sediment-dwelling organisms in most U.S. water bodies.

**Table 2-5. HHCB Evidence Table Summarizing Overall Confidence Derived for Environmental Risk Characterization**

| Exposure Pathway | Exposure Confidence | Hazard Confidence [a] | Risk Characterization Confidence |
|---|---|---|---|
| Surface water | Robust confidence in modeled exposure concentrations derived from TRI-reported data from industrial release COUs<br><br>Moderate-to-robust confidence in modeled concentrations as being representative of actual releases with a bias toward over-estimation | Robust: Acute exposure resulting in aquatic vertebrate and invertebrate species mortality | Robust (Section 2.4.2.3) |
| | | Robust: Chronic exposure to aquatic vertebrate species (78% lower *Pimephales promelas* survival and 54% slower growth over 36 days) | Moderate to robust (Section 2.4.2.3) |
| Sediment | Moderate-to-robust confidence in modeled concentrations as being representative of actual releases with a bias toward over-estimation | Robust: Chronic exposure to sediment-dwelling animal (49% lower *Lumbriculus variegatus* reproduction over 28 days) | Moderate-to-robust (Section 2.4.2.3) |
| Air | Robust in that HHCB is not expected in ambient air due to rapid degradation | Robust: No evidence of adverse effects on wild animal populations | Robust |
| Biosolids to soil | Moderate confidence in the highest measured biosolid concentration used to model high-end modeled soil HHCB | Robust: Chronic exposure to soil invertebrates (reduced earthworm [*Eisenia fetida*] reproduction over 28 days) and plants (reduced rapeseed [*Brassica napus*] biomass over 21 days) | Moderate-to-robust (Section 2.4.3.4) |
| Trophic transfer from water | Robust confidence in fish tissue concentrations for screening-level assessment and additional line of evidence from ADME-B and KABAM modeling | Robust: Chronic dietary exposure to terrestrial mammals (reduced reproduction over 2 generations) | Robust (Section 2.4.3.4) |
| Trophic transfer from soil | Robust confidence in high-end earthworm tissue concentrations derived using the highest report BCF value and the highest reported measured HHCB in soil. | Robust: Chronic dietary exposure to terrestrial mammals (reduced shrew reproduction over 2 generations) | Robust (Section 2.4.3.4) |

[a] EPA has robust confidence in the quality, consistency, strength and precision, and relevance of the studies used in determining the acute aquatic, chronic vertebrate, chronic invertebrate, and algal hazard thresholds (U.S. EPA, 2026y).

# 3 HUMAN HEALTH RISK ASSESSMENT

**HHCB – Human Health Risk Assessment (Section 3):**
**Key Points**

***Hazard Key Points (Section 3.1)***

- Decreased offspring bodyweight was the most sensitive and robust non-cancer effect.
- A non-cancer POD ($BMDL_5$ of 30 mg/kg-day) is used to characterize non-cancer risks from intermediate and chronic oral and inhalation exposures. A human equivalent dose (HED) of 7.09 mg/kg-day and a human equivalent concentration (HEC) of 38.6 mg/$m^3$ (3.65 ppm) were derived with a benchmark margin of exposure (MOE) of 30.
- No acute (all routes) or dermal (all durations) non-cancer hazard values were derived because the available evidence indicates it is unlikely that any adverse systemic or local effects will result at concentrations relevant to human exposures.
- Using the ReCAAP weight of evidence framework (Hilton et al., 2022), EPA determined that the absence of cancer bioassays does not impart scientific uncertainty in the risk characterization for HHCB. The non-cancer POD based on decreased offspring bodyweight is health-protective, including for any cancer potential and for PESS. Therefore, EPA did not derive a separate cancer hazard value.

***Exposure Key Points (Section 3.3)***

- Inhalation exposures were estimated for workers and consumers for COUs with the highest potential exposures.
- The highest exposure potential for workers was via dust inhalation during unloading of plastic materials; intermediate average daily doses up to $8.35\times10^{-2}$ mg/kg-day.
- The highest exposure potential for consumers was via aerosol from continuous action air fresheners; chronic average daily dose up to $1.27\times10^{-3}$ mg/kg-day.
- The highest oral exposures via drinking water and fish ingestion were for tribal populations; chronic average daily does up to $9.27\times10^{-2}$ mg/kg-day. Other pathways (ambient air and incidental surface water ingestion) were not pursued because drinking-water/fish consumption are expected to result in higher exposures.
- Aggregate exposures focused on three scenarios: (1) female workers of reproductive age (16–21 years) who inhale HHCB dust during plastic compounding and also consume fish and drinking water, (2) female consumers of reproductive age (11–15 years) who inhale HHCB mist from a continuous action air freshener and also consume fish and drinking water, and (3) infants (<1 year) who inhale HHCB mist from a continuous action air freshener and consume drinking water contaminated with HHCB.

***Risk Assessment Key Points (Section 3.4)***

- No potential non-cancer risk was identified for workers, consumers, or the general population.
- No potential aggregate risk was identified.
- PESS were considered throughout the exposure assessment, hazard identification, and dose-response analysis supporting this draft risk evaluation.

## 3.1 Summary of Human Health Hazards

This section summarizes the non-cancer and cancer human health hazards of HHCB. Detailed information is in Section 2 of the *Draft Human Health and Environmental Hazard Assessment for Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (also called the "Draft HHCB Human Health and Environmental Hazard Assessment" TSD) (U.S. EPA, 2026y).

### 3.1.1 Non-Cancer Human Health Hazards of HHCB

Non-cancer hazards of HHCB were characterized for the oral, inhalation, and dermal routes of exposure. PODs were derived, as appropriate, to support risk estimates for the general population, consumers, and workers across the identified COUs.

For the oral route of exposure, previous assessments by the U.S. EPA (OCSPP, 2014)and the European Chemicals Bureau (ECB) (ECB, 2008a, b) derived non-cancer hazard values based on developmental toxicity but noted uncertainty due to a small number of studies and due to the absence of multigenerational reproductive toxicity studies. Since these assessments, several developmental and reproductive toxicity studies became available to EPA, including an OECD 443 extended one-generation reproductive toxicity (EOGRT) study (IFF, 2021). In Section 2.3 of the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y), updated database was evaluated and determined that developmental toxicity was the only hazard outcome appropriate for dose-response analysis.

In Section 2.3.2 of the Draft HHCB Human Health and Environmental Hazard Assessment" TSD (U.S. EPA, 2026y), EPA considered the available studies on dermal absorption, acute and subchronic systemic dermal toxicity, dermal irritation, and dermal sensitization. No dermal hazards were observed for HHCB at concentrations above those that are relevant to human exposure. This is due in part to HHCB's lipophilicity(discussed in Section 2.3 of 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)* (U.S. EPA, 2026s)) which leads to retention on or within the skin and minimal entry into systemic circulation. Therefore, only oral and inhalation hazard values were derived to support risk estimates for these exposure routes.

No health effects relevant to setting an acute POD for any exposure route was identified. The available acute oral, inhalation, and dermal toxicity studies, as well as the EOGRT and developmental toxicity studies, indicate it is unlikely that any adverse effects will result following a single exposure at concentrations relevant to human exposures. Additionally, the POD for repeated exposures is expected to be protective of any potential acute hazard.

For intermediate and chronic durations of oral exposure, a POD of 30 mg/kg-day (human equivalent dose [HED] of 7.09 mg/kg-day) is proposed based on decreased offspring body weight. This POD was derived using benchmark dose modeling of F1offspring body weight data, which is the most sensitive endpoint from the EOGRT study in rats (IFF, 2021). Benchmark dose modeling was conducted on bodyweights for all measured pre-weaning and post-weaning timepoints, and the lowest $BMDL_5$ of 30 mg/kg-day from PNDs 4 and 14 was selected as the POD. This is protective of other effects identified in this study (delayed preputial separation in F1 offspring and decreased anogenital distance in F2 offspring) and is additionally protective of maternal toxicity noted in other studies. The proposed POD is also protective for PESS, including sensitive lifestages (pregnant women, infants, children, and adolescents) and potential exposures to HHCB via cord blood and breast milk. The HED was derived using ¾-body weight scaling. An interspecies uncertainty factor ($UF_A$) of 3 and an intraspecies uncertainty factor ($UF_H$) of 10 were applied, yielding a total UF of 30, which serves as the benchmark

MOE. Overall, based on the strengths, limitations, and uncertainties discussed in Section 2.4.4 of the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y), there is robust confidence in the proposed non-cancer POD. This POD will be used to characterize risk for intermediate and chronic oral exposure scenarios.

No suitable inhalation studies were available to derive route-specific PODs, so the intermediate/chronic oral POD was applied to evaluate inhalation risks. The oral HED was extrapolated to an inhalation human equivalent concentration (HEC) per EPA's *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry* (U.S. EPA, 1994) using updated body weight and breathing rate for continuous resting exposure from the EPA's *Exposure Factors Handbook* (U.S. EPA, 2011b). The oral HED and inhalation HEC used for non-cancer risk estimation from intermediate and chronic exposure are summarized in Table 3-1.

**Table 3-1. Non-Cancer HECs and HEDs Used to Estimate Risks**

| Exposure Scenario; Target Organ System | Duration of Exposure | POD (mg/kg-day) | Effect | HED [a] (mg/kg-day) | HEC [a] ($mg/m^3$) [ppm] | Benchmark MOE [b] | Reference, Overall Quality Determination |
|---|---|---|---|---|---|---|---|
| Intermediate, chronic; developmental toxicity | Pre-mating in F0 generation through PND 21–23 in F2 generation | $BMDL_{05}$ = 30 | Decreased body weight in F1 offspring on PNDs 4 and 14 | 7.09 | 38.6 [3.65] | $UF_A$ = 3<br>$UF_H$ = 10<br>*Total UF = 30* | (IFF, 2021), Acceptable/ Guideline [c] |

BMDL = benchmark dose (lower 95th percentile); HEC = human equivalent concentration; HED = human equivalent dose; MOE = margin of exposure; POD = point of departure; UFA = interspecies uncertainty factor; UFH = intraspecies uncertainty factor

[a] HED and HEC values were calculated based on the most sensitive BMDL of 30 mg/kg-day.

[b] EPA used allometric body weight scaling to the ¾-power to derive the HED. Consistent with EPA Guidance (U.S. EPA, 2011c), the interspecies uncertainty factor (UFA) was reduced from 10 to 3 to account remaining uncertainty associated with interspecies differences in toxicodynamics. EPA used a default intraspecies (UFH) of 10 to account for variation in sensitivity within human populations.

[c] Reference was evaluated using EPA's Office of Pesticide Program (OPP) Data Evaluation Record (DER) format.

### 3.1.2 Cancer Human Health Hazards of HHCB

Previous assessments did not evaluate cancer risk because no cancer bioassays were available. EPA's systematic review identified no new cancer bioassays. Therefore, EPA used elements of the Rethinking Chronic Toxicity and Carcinogenicity Assessment for Agrochemicals Project, or the ReCAAP weight of evidence framework to evaluate whether the lack of carcinogenicity studies imparts significant uncertainty on the human health risk assessment for HHCB (Hilton et al., 2022). Specifically, EPA evaluated the weight of evidence from physical and chemical properties, toxicokinetics, acute toxicity, subchronic toxicity, genotoxicity, hormone perturbation, immune system perturbation, mechanistic studies to support cancer MOA, and chronic toxicity. From these lines of evidence, EPA determined that HHCB has a low potential for bioaccumulation in human tissues; produces no acute toxicity, irritation, or sensitization; causes no adverse organ weight changes and no pre-neoplastic lesions after repeated subchronic exposure; is not genotoxic; is not an endocrine disruptor *in vivo*; and is not toxic to the immune system. EPA concluded that the non-cancer POD selected for characterizing risk from intermediate and chronic exposure to HHCB is health-protective, including of any potential cancer effects. Therefore, EPA did not conduct a dose-response assessment for cancer and did not quantitatively evaluate HHCB for carcinogenic risk to human health.

## 3.2 Conceptual Models

Conceptual models consider exposure pathways and routes along with hazards. In this human health risk assessment, a tiered approach is used, prioritizing COUs with the highest potential for HHCB exposures and risk based on the evaluated population and relevant exposure routes and pathways. As detailed in Section 3.1.1, HHCB shows no dermal hazard, with no local or systemic effects observed in the available animal and human studies. Accordingly, dermal hazards are not depicted in the conceptual models. HHCB is also not acutely hazardous by any route, so the conceptual models illustrate only intermediate and chronic hazards.

### 3.2.1 Occupational

Workers, including occupational non-users (ONUs) [3], may experience inhalation exposures (vapor, mists, and dust) and dermal contact with solid and liquid HHCB. Figure 3-1 illustrates the conceptual exposure model for industrial and commercial activities affecting workers and ONUs: solid lines indicate potential exposure pathways assessed in this evaluation, and light-gray dashed lines represent pathways considered possible but not quantified because risk is expected to be negligible. ONUs are not assessed separately (light-gray dashed line), but exposures are expected to be similar or lower than worker exposures.

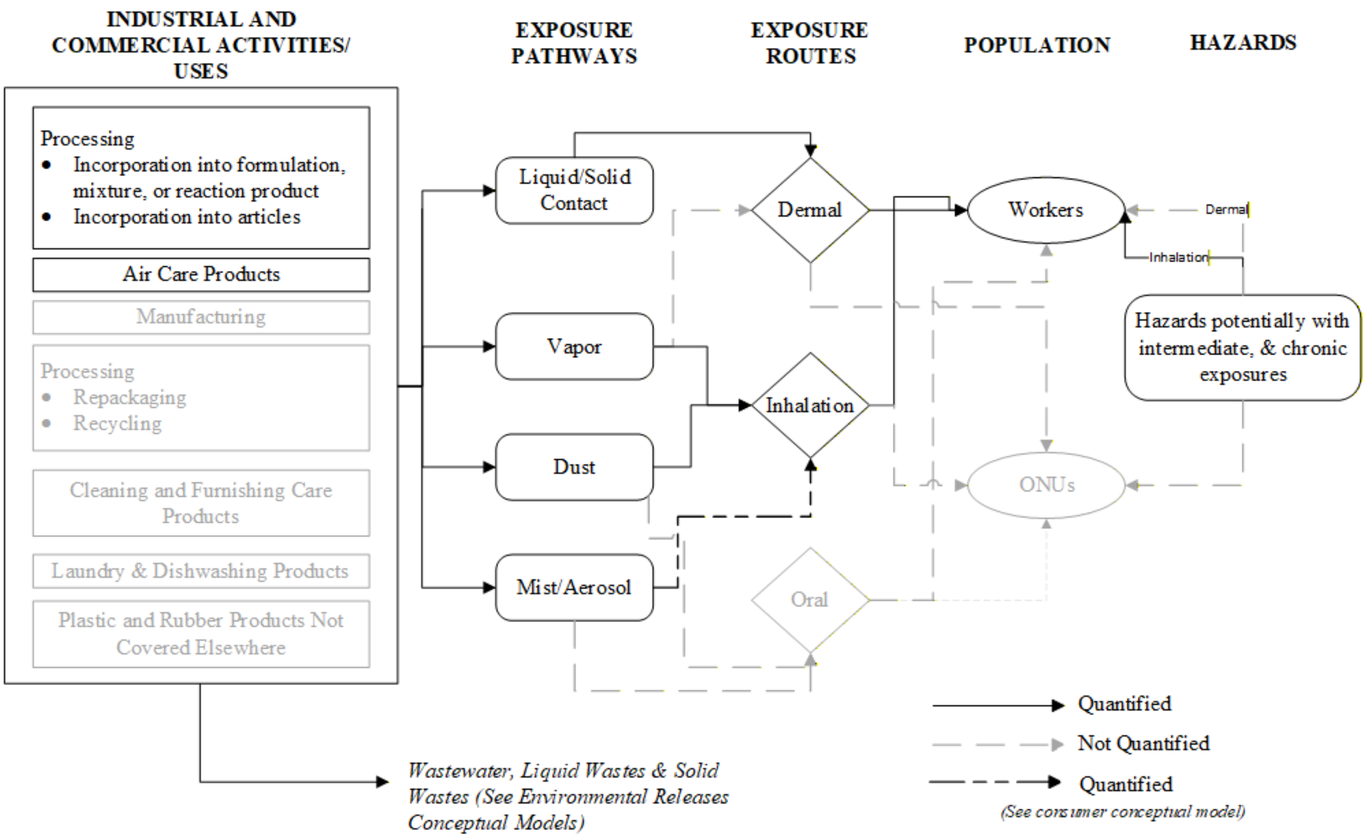


**Figure 3-1. Occupational Conceptual Model of Pathways Assessed**

Note: The scenarios assessed were selected because they represent the highest potential exposure. These scenarios also serve as a protective screen for potential exposures to HHCB via inhalation of vapor or dust among occupational, consumer and the general population.

[3] ONUs are employed individuals who do not directly handle HHCB but may be indirectly exposed to it as part of their employment.

As a screening approach, the COUs with the highest exposure potential (also called "sentinel COUs") were selected: (1) Processing – Incorporation into formulation, mixture, or reaction products – Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Other: fragrance mixtures and fragrance raw materials; and (2) Processing – Incorporation into articles – Odor agent in: Plastics material and resin manufacturing (Section 3.3.1). These activities were assessed for dermal contact with liquid/solid contact and inhalation exposure to dust and vapor among workers. Because no dermal hazard was identified, the risk characterization focuses on intermediate and chronic inhalation exposures (Section 3.1.1). Worker oral exposure is not assessed given the low likelihood of hand-to-mouth behaviors in occupational settings and the absence of COU-specific data indicating oral exposure. Mist exposure is included in the occupational conceptual model for air care products; however, this assessment uses a consumer scenario as a surrogate exposure estimate that applies conservative assumptions expected to be protective of worker exposures (see Figure 3-2).

### 3.2.2 Consumer

Consumer and commercial users may experience inhalation and dermal exposures. Figure 3-2 summarizes relevant TSCA consumer or commercial products. Solid lines indicate pathways assessed; light-gray dashed lines represent plausible pathways not quantified because exposure or risk is expected to be negligible. Dermal risks were not quantified given no dermal hazards (Section 3.1.1). Direct users are assumed to have higher exposures than bystanders; quantified exposures were estimated for both users and bystanders. A screening approach was used to assess long-term inhalation exposures from continuous action (spray) air fresheners to be protective of other consumer and commercial use scenarios (Section 3.3.2). Direct oral consumer exposure is not expected based on product use patterns, though incidental ingestion may occur.

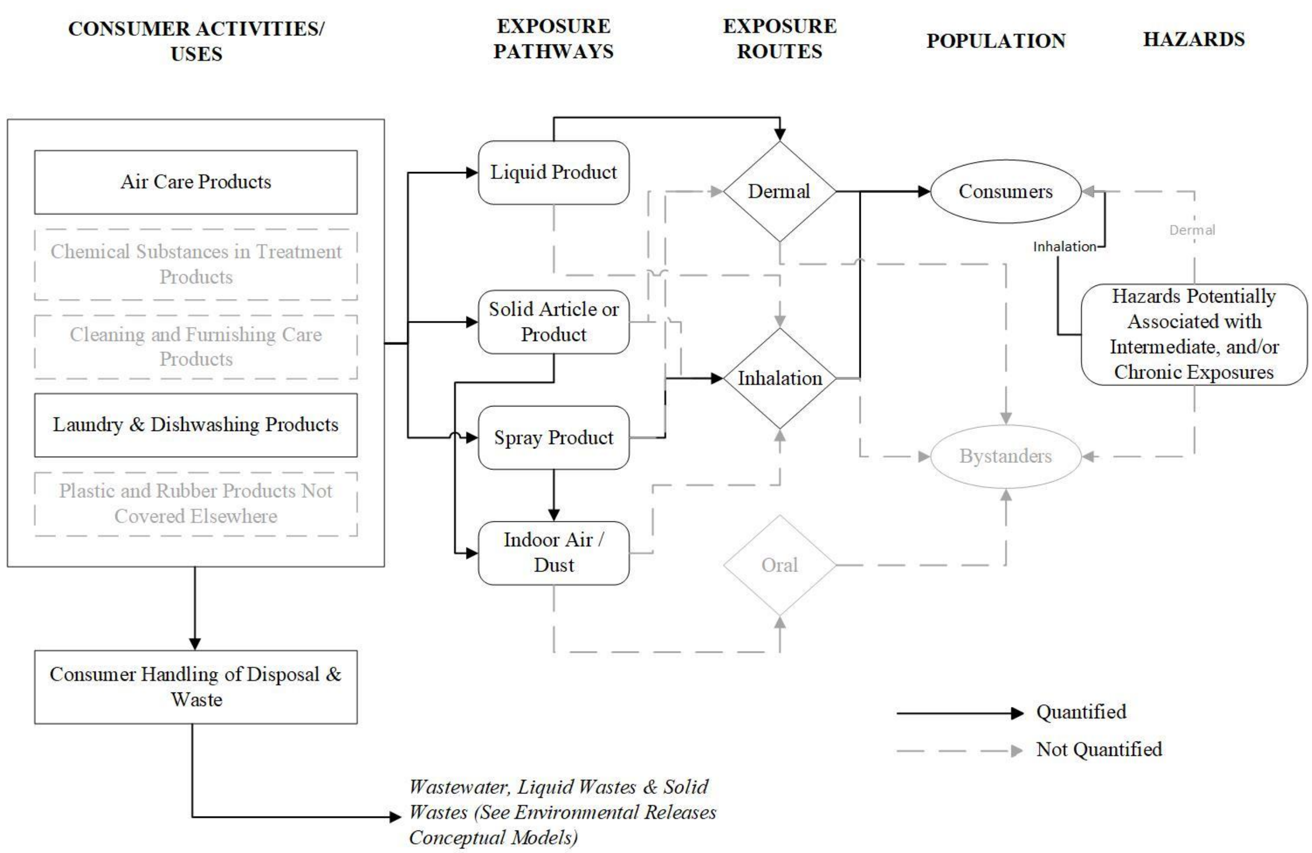


**Figure 3-2. Consumer Exposure Model of Scenarios Assessed**

### 3.2.3 General Population

General population exposure is expected primarily via the surface water pathway. As described in Section 1.4, HHCB enters ambient surface water via industrial releases and municipal wastewater discharges (POTWs) from down-the-drain disposals from products containing HHCB (Figure 3-3). Once in surface water, exposure can occur via drinking water sourced from those waters, fish consumption (HHCB in fish tissues), and incidental contact and ingestion during recreational activities. Ambient air inhalation exposures from industrial releases are discussed qualitatively, as the industrial releases to air are minimal (Section 1.4), and HHCB is not expected to persist due to rapid photodegradation (Section 1.3). Near-field occupational (Section 3.2.1) and consumer (Section 3.2.2) exposure scenarios assessed for inhalation are protective of the potential ambient air inhalation exposures. Therefore, exposure via this pathway is not quantified in the general population assessment.

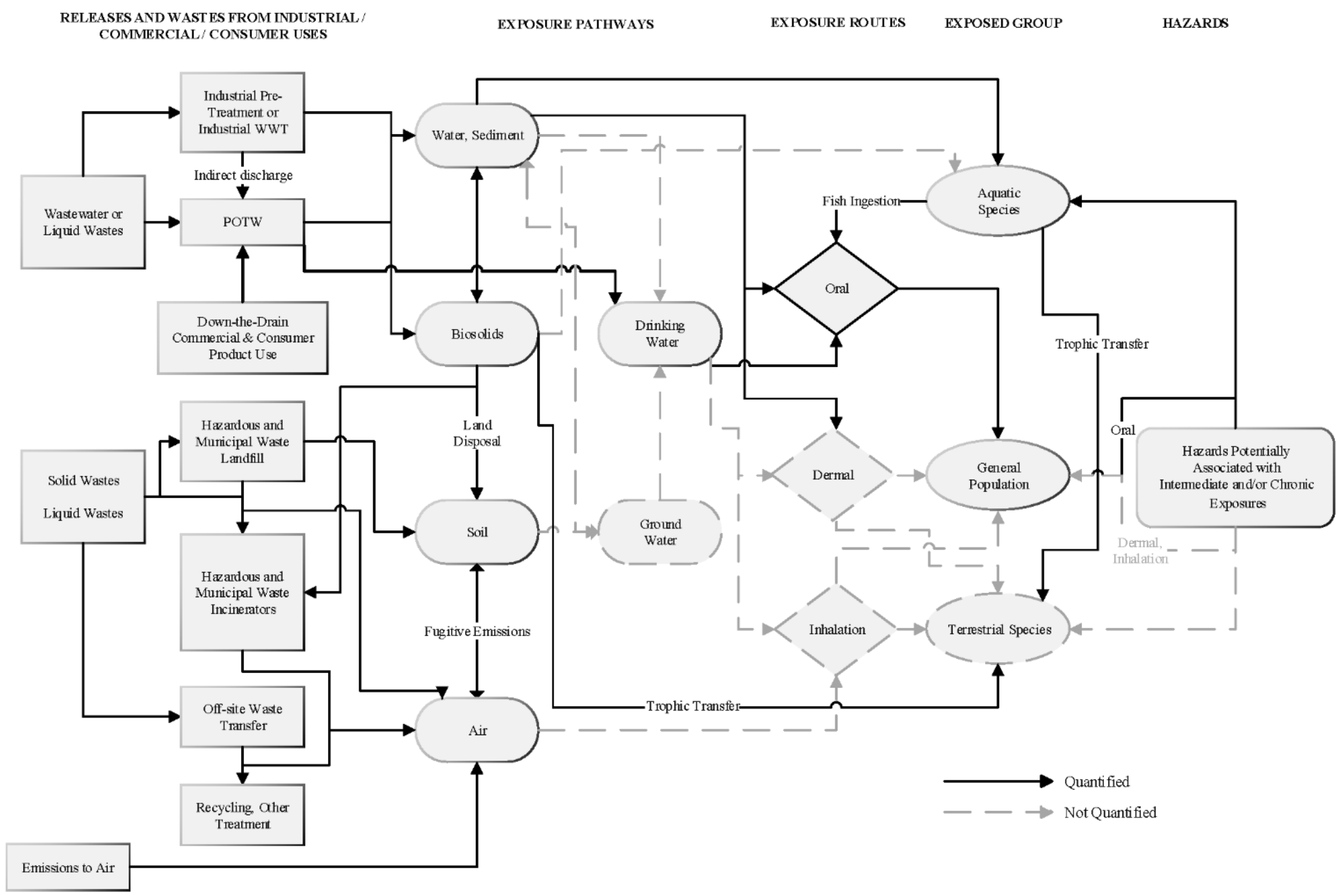


**Figure 3-3. General Population and Environmental Exposure Model of Scenarios Assessed**

A tiered analysis was employed to assess risk to the general population. Drinking water and fish consumption were prioritized due to the higher potential concentrations (Section 3.3.3). Incidental recreational ingestion from swimming was not pursued further; drinking water exposure serves as a protective scenario.

### 3.2.4 Aggregate and Sentinel

Because inhalation and oral hazard values are based on same systemic endpoint—decreased offspring bodyweight in rats (Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)) aggregate exposures across routes, pathways, and sources were considered. Individuals may be exposed via multiple routes (*e.g.,* inhalation, oral), pathways (indoor air and drinking water), and sources (worker activities and use of consumer product). Risk associated with three long-term aggregate scenarios were estimated by combining routinely expected exposure pathways as follows:

- **Aggregate Exposure Scenario 1 (Worker + Drinking Water + Fish Ingestion [Adults, 21+ Years]):** Workplace inhalation (HHCB dust during compounding/converting) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 2.3 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)).
- **Aggregate Exposure Scenario 2 (Consumer + Drinking Water + Fish Ingestion [Adults, 21+ Years]):** Consumer inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 2.3 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)).
- **Aggregate Exposure Scenario 3 (Consumer [Infants, <1 Year] + Drinking Water):** Consumer (infants) inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water.

These scenarios were selected because they represent the highest potential exposures across high-end exposure pathways for a screening-level aggregate exposures analysis. Although these aggregate scenarios may not reflect the most likely or common HHCB exposures, the scenarios provide examples of possible aggregate exposure pathways.

Sentinel exposures, which represent a plausible upper bound of exposure relative to all other exposures within a broad category of similar or related exposures, are captured throughout this draft assessment using screening-level or high-end exposure scenarios with high-end inputs and output estimates.

### 3.2.5 Populations and Durations of Exposures Assessed

The conceptual models presented in Section 3.2 detail exposure pathways for human populations. Human health risks were evaluated for intermediate and chronic exposure scenarios based on available exposure and hazard data for HHCB and the relevant populations for each.

Human populations assessed include:

- Workers;
- Consumers, including infants (<1 year), toddlers (1–2 years), children (3–5 years and 6–10 years), young teens (11–15 years), teenagers (16–20 years) and adults (21+ years);
- Bystanders, including infants (<1 year), toddlers (1–2 years), and children (3–5 years and 6–10 years); and
- General population, including infants, children, youth, and adults.

Note that the age groups for consumers, bystanders, and general population are different because each life stage used unique exposure factors (*e.g.,* mouthing, drinking water ingestion, fish consumption rates). These exposure factors are described in EPA's *Exposure Factors Handbook* (U.S. EPA, 2011b).

### 3.2.6 Potentially Exposed or Susceptible Subpopulations

TSCA section 6(b)(4)(A) requires that risk evaluations "determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other non-risk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator, under the conditions of use." TSCA section 3(12) defines a PESS as "a group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, or the elderly."

This draft risk evaluation considers PESS throughout the human health risk assessment (Section 3), including exposure assessment, hazard identification, and dose-response analysis. PESS addressed include women of reproductive age; pregnant women, infants, children and adolescents; frequent users of products or articles with high HHCB concentrations; workers; populations near releasing facilities (*e.g.,* fenceline communities); and high fish consumers (*i.e.,* subsistence fisher and tribal populations). These groups are considered PESS because some have higher exposure on a body weight basis (*e.g.,* infants, children, adolescents), while others may experience aggregate or sentinel exposures due to occupational activities, frequent/high-intensity product use, proximity to releasing facilities, or fish-based diets.

Section 3.4.5 summarizes how PESS were incorporated into this draft risk evaluation through consideration of potentially increased exposures and/or potentially increased biological susceptibility and summarizes additional sources of uncertainty related to consideration of PESS.

## 3.3 Summary of Human Exposures

This draft risk evaluation characterizes occupational, consumer, and general population exposures to HHCB, including PESS (workers, children, women of childbearing age, subsistence and tribal populations). Potential routes include inhalation (vapor, mist or dust), oral ingestion (drinking water, human milk, fish, soil), and dermal contact. A tiered human exposure approach was used combining screening-level (upper bound/high-end) analyses with more refined assessments tailored to specific populations, routes, and pathways.

The Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x) draws on monitoring data and modeled estimates, applying peer-reviewed models with inputs such as production/use volumes, processing temperatures, and exposure frequencies. The potential occupational exposure across all COUs were considered; however, only two scenarios (Formulation of Fragrance Oil; Plastic Compounding/Converting) were quantitatively assessed as these scenarios are expected to represent the highest potential occupational exposure across all COUs. Continuous 24/7 use of air fresheners for one year in small 15 $m^3$ rooms (*e.g.,* bathrooms, dorm rooms, small rooms within a home) is expected to represent the highest potential consumer exposure across all relevant COUs as well as for occupational exposures from use of similar products. As discussed in Section 2.2.2.1 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x), exposure from use of a continuous-action air fresheners in vehicles (*e.g.,* plug-ins, hanging "paper tree" fresheners, diffusers) is expected to be captured by the 24/7 use of continuous-action air freshener in a small residential room (15 $m^3$) used in this screening-level assessment. For general population drinking water exposure, the combined commercial plus consumer down-the-drain release evaluated at the P95 POTW receiving-water concentration provides a high-end screening concentration that captures all individual COUs. Exposures for ONUs and bystanders were not separately estimated because exposures are expected to be like or lower than direct-user exposures.

As HHCB is not acutely hazardous, only intermediate and chronic exposures were evaluated (See Section 2.3 in (U.S. EPA, 2026y)). No dermal hazard was identified; therefore, while dermal exposure may exist (see dermal exposure estimates in Appendix C in (U.S. EPA, 2026x)), dermal exposure estimates were not used in risk characterization. Oral exposures to workers or consumers are not expected due to the low likelihood of hand-to-mouth behaviors and the absence of COU-specific evidence of oral exposure for workers or consumers. Direct oral consumer exposures are not expected based on product use patterns, although incidental ingestion may occur.

### 3.3.1 Occupational Exposures

Occupational exposures were estimated by modeling, either deterministic or probabilistic calculations (Monte Carlo). Probabilistic simulations generated full exposure distributions using the full distribution range of parameters, with the 50th percentile as the central tendency and the 95th percentile as the high-end. Deterministic estimates used surrogate monitoring data (50th percentile for the central tendency) and a regulatory limit for high-end. Estimated air concentrations were then converted to intermediate and chronic average daily doses (IADD and CADD) using exposure duration, frequency, breathing rate, and body weight (see Section 2.1 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)).

#### 3.3.1.1 Summary of Inhalation Exposure Assessment

Workers may be exposed via inhalation to HHCB as mist, vapor and dust. Mist exposure was not estimated because the conservative continuous action air freshener consumer scenario (smaller residential spaces, lower ventilation, near-continuous use) is expected to be protective of workplace mist exposure. Two TSCA COU scenarios for vapor and dust inhalation were modeled, with estimates presented in Table 3-2.

**Table 3-2. Average Daily Doses for Occupational Exposures**

| Highest Exposure Scenario | COU | Worker Type | Intermediate Average Daily Dose (IADD; mg/kg-day) | | Chronic Average Daily Dose (CADD; mg/kg-day) | |
|---|---|---|---|---|---|---|
| | | | 50th Percentile | 95th Percentile or Regulatory Limit [a] | 50th Percentile | 95th Percentile or Regulatory Limit [a] |
| Formulation of Fragrance Oils | Processing – Incorporation into formulation, mixture or reaction product – Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Other: fragrance mixtures and fragrance raw materials | Average Adult | 1.86E−04 | 1.69E−03 | 1.74E−04 | 1.58E−03 |
| | | Women between 16–21 (most sensitive group) | 2.26E−04 | 2.05E−03 | 2.11E−04 | 1.91E−03 |
| Plastic Compounding/ Converting | Processing – Incorporation into articles – Odor agent in: Plastics material and resin manufacturing | Average Adult | 1.65E−02 | 6.88E−02 | 1.5E−02 | 6.42E−02 |
| | | Women age between 16–21 (most sensitive group) | 2.00E−02 | 8.35E−02 | 1.87E−02 | 7.80E−02 |

[a] The 95th percentile of the monitoring data for PNOR exceeds the regulatory limit for PNOR; therefore, the regulatory limit (15 $mg/m^3$) was used to represent a "high-end" exposure estimate.

For vapor exposure, the modeled scenario was for the OES, Formulation of fragrance oils, in which workers unload HHCB, mix it with other components, and package the final product. This scenario was selected because unloading occurs at elevated temperatures, increasing volatilization and inhalation potential, and is most applicable where highly concentrated HHCB is handled. Standard vapor emission and room-mixing models (with Monte Carlo simulations) were used to estimate concentrations during unloading, container and equipment cleaning, sampling, and packaging (see Appendix A of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)). Activity-specific concentrations were time-weighted to derive an 8-hour time weighted average (TWA) for a worker completing all tasks, which was then used to calculate 50th and 95th percentile average daily doses (ADDs) of HHCB (see Table 3-2).

For dust exposure, inhalation during unloading and loading in plastic compounding/converting was modeled. This scenario was chosen because it involves relatively high concentrations, large volumes, and frequent dust-generating operations. The Particulate, Not Otherwise Regulated (PNOR) Central and High-end Exposure model (U.S. EPA, 2021) was applied, which uses OSHA PNOR monitoring data categorized by industry sector (NAICS) and is not task-specific. Key inputs are the selected industry sector and the weight concentration of HHCB in the dust. In this approach, dust is assumed to be generated solely from HHCB-related activities and is proportional to the concentration of HHCB in the bulk material (finished plastic material). The model provides an 8-hour TWA concentration for total HHCB-bearing dust at the central (50th percentile) and high-end (regulatory limit) levels (see Appendix A of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x) for full details on the modeling approaches and results).

#### 3.3.1.2 Weight of Scientific Evidence Conclusions for Occupational Exposure

There is moderate-to-robust confidence in the scientific evidence that the estimated modeled inhalation exposure estimates for HHCB are screening estimates for use in occupational settings. However, confidence in the precision of the HHCB vapor exposure estimates as reflections of actual worker exposure is moderate.

Vapor inhalation exposure estimates are considered protective of other scenarios due to the higher vapor pressure used representative of elevated handling temperatures that are used when handling concentrated HHCB due to its viscous nature. These conditions are most relevant during manufacturing, repackaging, and fragrance-oil formulation; the formulation scenario had the strongest supporting data for parametrization. Uncertainties including batch size, indoors vs. outdoors operations, and loading duration could lead to over- or underestimation. Use of Monte Carlo analysis (100,000 iterations) was used to capture variability in those parameters, increasing confidence in the results. These modeled results do not account for any engineering controls, which may reduce the HHCB air concentration that workers experienced.

Dust exposure modeling relied on OSHA PNOR monitoring data categorized by industry groups, which provide a representative range of worker exposures to dust but are not task specific. As the 95th percentile of monitoring data exceeds the regulatory limit, the PNOR regulatory limit was used as the high-end. The estimates assume all workplace dust originates from plastic pellets, all HHCB in the dust is bioavailable, and HHCB concentrations in the plastic pellets (unknown) equals those in the finished plastic articles. The assumption that all workplace dust is generated from plastic pellets is likely an overestimate as workplace dust typically contains multiple constituents that dilute the HHCB fraction.

### 3.3.2 Consumer Exposures

Consumer exposures to inhaled mists were estimated by modeling using deterministic calculations generated with CEM. Deterministic estimates were based on a high-end duration, high-end frequency of use and weight fraction for continuous action air fresheners (per SDSs (Chase Products, 2025)), smallest room of use (per CEM v3.2 (U.S. EPA, 2023a) and EPA's *Exposure Factors Handbook* (U.S. EPA, 2011a)), and the conservative assumption of 24/7 occupancy in one small room or across similar rooms of use. Estimated air concentrations were then converted to CADD using exposure duration, frequency, breathing rate, and body weight (U.S. EPA, 2023a). For further details, see Section 2.2 of Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x).

#### 3.3.2.1 Summary of Inhalation Exposure Scenarios

The consumer exposure assessment focused on inhalation of HHCB as mist. Vapor and dust were not modeled because the conservative occupational scenarios are expected to bound consumer vapor or dust exposures (See Sections 2.1.1 and 2.1.2 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)). One TSCA COU inhalation scenario was used for screening purposes: 24/7 mist exposure to continuous action air fresheners in a small residential room or across similar rooms. For a detailed description of the product selection considerations for this screening analysis, see Section 2.2 and Appendix E.2 of the Draft HHCB Human Exposure Assessment TSD (U.S. EPA, 2026x). The consumer exposure assessment for HHCB considered all age groups since anyone from the population may be exposed to aerosolized continuous-action air fresheners including drivers. Although, due to lower occupancy timeframes, larger interior space, higher ventilation and lower product usage, EPA expects consumer and commercial HHCB exposures to be lower and captured by the 24/7 use of continuous-action air freshener in a small residential room (15 $m^3$) used in this screening-level assessment.

#### 3.3.2.2 Summary of Inhalation Exposure Assessment

Table 3-3 presents HHCB mist concentrations from continuous-action air fresheners and associated exposure doses for adults, youth, children, and infants. These values are upper bounds, reflecting a conservative assumption of 24/7 occupancy of a small room (*e.g.,* bathroom, dorm room, small room within a home) or movements between such rooms with continuous action air fresheners for one year. Infants (<1 year) have the highest estimated average daily dose ($1.27\times10^{-3}$ mg/kg/day) due to a higher inhalation rate per body weight. These estimates provide insight into potential consumer exposures to HHCB among individuals who may be present in a small space or housebound for extended periods (*i.e.,* elderly, infants in small nurseries, college students in dorm rooms, and individuals with severe illness or disability in small bedrooms). In addition, while short-term and intermediate consumer exposures were not further assessed, it is important to note that due to the continuous nature of the exposure scenario, the estimated long-term doses for consumer users of aerosolized continuous action air fresheners are applicable to intermediate timeframes (*i.e.,* 30 days) and chronic timeframes (*i.e.,* 1 year) of exposure as well.

**Table 3-3. Consumer Mist Inhalation Dose Estimates[a]**

| Scenario | Consumer Population | Annual Daily Average Concentration ($mg/m^3$) | Chronic Non-Cancer Exposure Time (hours/day) | Chronic Non-Cancer Exposure Frequency (days/year) | Annual Daily Average Dose (mg/kg/day) [c] |
|---|---|---|---|---|---|
| Continuous action air fresheners | Adult 21+ years | 8.95E−04 | 24 | 365 | 1.99E−04 |
| | Youth 16–20 years [b] | | | | 2.35E−04 |
| | Youth 11–15 years | | | | 2.95E−04 |
| | Child 6–10 years | | | | 4.46E−04 |
| | Child 3–5 years | | | | 7.62E−04 |
| | Infant 1–2 years | | | | 1.23E−03 |
| | Infant <1 year | | | | **1.27E−03** |

[a] Adapted from Table 3-3 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x).
[b] The body weight for this age group was adjusted from 71.6 kg (*Exposure Factors Handbook* (U.S. EPA, 2011a)) to 65.9 kg per latest ECRAD guidance on the consideration of body weights for the assessment of exposures and risks among females of reproductive age.
[c] Doses were derived using CEM.
**Bold** font indicates highest dose.

#### 3.3.2.3 Weight of Scientific Evidence Conclusions for Consumer Exposure

Inhalation dose estimates for HHCB mist from continuous-action air fresheners are product-specific and represent upper-bound, not typical, exposures (Section 2.2.2 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)). Inputs (HHCB concentration, release rate, duration) were taken from product SDS (Chase Products, 2025) and manufacturer description, with CEM modeling informed by room size, ventilation, behavioral and biological data (*e.g.,* inhalation rates, body weights) from the *Exposure Factors Handbook* (U.S. EPA, 2011a) as well as physical and chemical properties (See Section 1.3). Conservative assumptions – small room, 24 hours/day occupancy, and the highest product weight fraction – were applied. More realistic assumptions (*e.g.,* movement to larger rooms or areas without fresheners) would be expected to reduce exposure estimates. These high-end results exceed those expected for other consumer products. In conclusion, there is moderate-to-robust confidence that the estimates represent high-end consumer and commercial exposure levels (see Section 3.3.1.1), but only slight confidence that these estimates reflect typical real-world exposures due to conservative inputs.

### 3.3.3 General Population Exposures

The general population may be exposed to HHCB through multiple media, but several pathways are negligible and not pursued further. The primary exposures considered are via the surface water pathway, downstream of environmental releases. Oral exposure via consumption of fish that have taken up HHCB into their tissues is considered, in addition to consumption of drinking water containing HHCB. HHCB is detected in surface waters nationwide and is expected to be present in higher concentrations near POTW effluent due to down-the-drain loading (Section 1.4.3.1). Potential intake via human milk in infants and children is also considered. Exposures via inhalation are unlikely to be substantial for the general population due to minimal industrial releases to air (Section 1.4), and rapid degradation by photolysis (Section 1.3). Near-field occupational (Section 3.3.1) and consumer (Section 3.3.2) exposure scenarios assessed for inhalation are protective of the potential ambient air inhalation exposures. Additionally, dermal exposure is not expected to be hazardous (Section 1.4); therefore, these pathways are not further evaluated. Incidental oral exposure, such as during swimming and other recreational activities, are also not evaluated further because exposure is expected to be lower than long-term drinking water exposure. The subsections below summarize the general population exposure scenarios.

General population exposure is centered on the water pathway, reflecting HHCB prevalence in surface water from down-the-drain releases. Down-the-drain loading of HHCB is derived from disposal of products used in commercial (business) and consumer (residential) settings. Because these disposals are not directly and independently discharged to the environment, but rather transferred from multiple locations (*i.e.,* multiple businesses and multiple residences within the same community) to a central wastewater treatment plant, the addition of multiple product types, as well as both the commercial and consumer settings, were considered at the community scale. After treatment, this combined wastewater is discharged as a single point source to the receiving water, where exposure can subsequently occur for the general population.

The highest potential general population exposure is from chronic fish consumption, followed by the considerably lower exposure associated with chronic drinking water ingestion. Both pathways use high-end surface water modeling based on the combined commercial and consumer products down-the-drain releases, anchored to the 95th percentile POTW receiving-water scenario (Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s), Section 4.2.2). Scenarios assume a continuous chronic exposure to high-end water and fish-tissue concentrations as a screening approach, relying on protective assumptions of routinely ingesting fish that reside exclusively where high concentrations of HHCB are found, and drinking water that has not undergone additional treatment or dilution beyond the point of release from the POTW.

The estimates of HHCB exposure due to fish consumption are based on equations that consider surface water concentration, modeled fish tissue concentrations, and fish ingestion rates. Inputs and intermediate calculation values for the equations used in this assessment are included in the *Draft Fish Ingestion Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026v), and presented in greater detail 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, 2026x). Refinement of the fish tissue concentrations estimated for this analysis included the application of EPA's KABAM, as detailed in Appendix F of the Draft HHCB Environmental Exposure Assessment TSD (U.S. EPA, 2026s). This more advanced food web and uptake model provided whole fish tissue concentrations ranging from 6.1 to 8.5 mg/kg—even when considering constant exposure to the high-end surface water concentration of 25.4 µg/L. High-end (90th percentile) ingestion rates for the general population across all age groups were below 1 g/kg-day, and the subsistence fisher rate of 1.78 g/kg-day was used as a protective input to represent general population consumption. Selected tribal central tendency and high-end intake rates were notably higher at 2.7 and 10.9 g/kg-day, respectively.

#### 3.3.3.1 Summary of Oral Exposures Assessment

Table 3-4 reports modeled whole-fish HHCB concentrations and adult ADDs based on PSC estimates of combined down-the-drain releases (Section 1.4.3.1).

**Table 3-4. Estimated Exposures via Fish Ingestion**

| Scenario | Surface Water Concentration (SWC; µg/L) | Fish Tissue Concentration (mg/kg) [a] | ADD, Adults (mg/kg-day) | | | |
|---|---|---|---|---|---|---|
| | | | Gen Pop., 90th Percentile IR | Subsistence Fisher IR | Tribal, Current Central Tendency IR | Tribal, Current High-End IR |
| Consumer Plus Commercial Combined DTD (KABAM) | 25.4 [b] (P95 POTW) | 8.5 Whole fish | 5.36E−04 | 1.51E−02 | 2.30E−02 | **9.27E−02** |
| Highest monitored fish tissue (common carp, whole fish) | N/A | 2.10 Whole fish | 5.83E−04 | 3.74E−03 | 5.67E−03 | 2.29E−02 |

ADD = average daily dose; BCF = bioconcentration factor; DTD = down-the-drain; IR = (fish) ingestion rate; KABAM = $K_{OW}$ (based) Aquatic BioAccumulation Model; SWC = surface water concentration
[a] $Fish\ Tissue\ Conc. = SWC \times BCF \times 0.001$ mg/µg
[b] A 92% removal efficiency for HHCB is applied to these modeled releases.
**Bold** font indicates highest dose.

The highest modeled whole-fish concentration is 8.5 mg/kg, from the combined consumer plus commercial POTW discharges. This modeled fish concentration calculated from the highest measured surface-water concentration (25.5 µg/L), downstream of a California POTW, has a negligible difference and is essentially equal to the 8.5 mg/kg calculated for this modeled scenario. The P95 POTW scenario reflects population served and receiving-water flow, yielding concentrations higher than 95% of POTWs nationally. By comparison, the highest measured whole-fish concentration is 2.1 mg/kg (common carp, Phoenix, Arizona; (Ramirez et al., 2009)). Site analysis places the California location near a 90th-percentile POTW and the Phoenix site near a 95th-percentile POTW. The P95 POTW scenario represents a combination of POTW population data and receiving water body flow, such that the concentration in the receiving water body is expected to be higher than at 95% of the POTWs in the country (*i.e.,* in the top 5% of environmental concentrations at a point of release).

Drinking water exposure concentrations and doses are presented in Table 3-5. For this protective screening assessment, the concentration in the receiving water from the 95th POTW modeled combined down-the-drain scenario was applied as the chronic concentration in finished drinking water, with no further dilution, degradation, or drinking water removal efficiency applied. For reference, the highest monitored surface water value from the WQP was also considered.

**Table 3-5. Estimated Exposures via Drinking Water**

| Scenario | Estimated Surface Water Concentrations Harmonic Mean Conc. (µg/L) | Adult (21+ years) ADD (mg/kg-day) | Infant (Birth to <1 year) ADD (mg/kg-day) | Toddler (1–5 years) ADD (mg/kg-day) |
|---|---|---|---|---|
| Combined modeled commercial plus consumer down-the-drain release with the P95 POTW scenario[a] | 21.2 | 2.33E−04 | 5.95E−04 | 2.55E−04 |
| Highest measured surface water[b] | 25.5 | 2.80E−04 | **7.16E−04** | 3.07E−04 |

ADD = average daily dose; POTW = publicly owned treatment works
[a] Only this scenario was used in the general population screening assessment because it resulted in the highest surface water concentrations. A 92% removal efficiency was applied for the wastewater, and no further drinking water removal efficiency was applied.
[b] Water Quality Portal database reported the highest monitored surface water concentration from California as described further in the Draft HHCB Environmental Exposure Assessment TSD (U.S. EPA, 2026s). This single maximum value does not correspond to either the 30Q5 or harmonic mean concentrations; nevertheless, it was used in both comparisons of modeled versus monitored surface water exposure estimates. Note that monitored concentrations are source-agnostic and cannot be attributed to specific TSCA COUs.
**Bold** font indicates highest dose.

Similarities between the P95 modeled surface water concentration and a measured concentration at a P90 POTW do not imply model underestimation. Monitoring reflects all HHCB sources (not only TSCA COUs) and may differ from modeled point of release conditions. Advanced treatment, multiple waste streams, sampling timing, and flow can lower environmental concentrations relative to model outputs. In addition, modeled fish tissues assume constant exposure to high concentrations of HHCB near the outfall; mobile fish experiencing variable concentrations would accumulate less HHCB, yielding lower observed tissue levels.

#### 3.3.3.2 Weight of Scientific Evidence Conclusions for General Population Exposure

Confidence in the distribution of surface water concentrations at POTW outfalls is robust. The distribution of available monitoring data generally aligns with the combined commercial plus consumer down-the-drain POTW scenarios assumptions and results. P50 results indicate that concentrations at most POTW discharge sites are low. Although the WQP surface water monitoring data (Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s), Section 4.2) come from diverse studies and locations not necessarily targeting POTWs receiving waters, and may not be statistically representative nationally, most samples indicate low or non-detect HHCB. However, elevated monitored concentrations (25 µg/L), in water near POTW outfalls are consistent with modeling, indicating that under certain conditions, higher HHCB concentrations can occur in immediate receiving water.

Refinement using KABAM yields fish tissues of moderate confidence given the input surface water concentrations. While ingestion-rate distributions are robust, it is uncertain that fish with high-end tissue concentrations (*i.e.,* those staying near high-end outfalls) are routinely harvested in large amounts. Accordingly, confidence in the high-end exposure estimates is slight-to-moderate.

### 3.3.4 Human Milk Exposures

EPA identified one study reporting HHCB concentrations in milk in U.S. populations (Reiner et al., 2007) detailed within the Draft HHCB Human Exposure Assessment within Section 3.3.1 (U.S. EPA, 2026x). Several small studies (sample size <100) from Asian and European countries also reported HHCB concentrations in human milk. Although the study locations are not necessarily representative of

U.S. exposures, these studies confirm this exposure pathway is possible (see Table_Apx A-2 in (OCSPP, 2014)). Based on the weight of evidence, EPA has slight-to-moderate confidence that the monitoring exposure estimates reflect real-world infant exposures to HHCB via human milk in the general U.S. population. This is because the one available study conducted in U.S. populations analyzed milk from a small sample (39 women) from the same state. For more information on the available biomonitoring data for HHCB, see the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x).

### 3.3.5 Aggregate Human Exposure Assessment

#### 3.3.5.1 Aggregate and Sentinel Analysis

The same systemic endpoint—decreased offspring bodyweight in rats after developmental exposure—was used to evaluate oral and inhalation risks; therefore, aggregate exposure across these routes was considered. Individuals may be exposed through different combinations of pathways (e.g., workplace inhalation and drinking water ingestion). Dermal hazard effects were not identified (Section 3.1), therefore, aggregation was limited to the inhalation and oral routes.

For the general population, exposures to HHCB may occur from multiple COUs when the use of commercial and consumer products results in down-the-drain releases to the same POTW, which then discharges into water bodies where drinking water or fish are sourced. Such risks are accounted for in Section 3.3.3.1.

As presented in Section 3.4.2 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x), exposures are aggregated for individuals exposed to HHCB at their workplace and through consumption of fish and drinking water that contain HHCB from multiple COUs. Additionally, consumer exposure was also aggregated with general population fish and drinking water exposures, using a subsistence-fishing ingestion rate. Analysis focused on common, reasonably anticipated aggregate scenarios and exposure to PESS including women of reproductive age and infants (Section 3.2.6). Exposures are based on average adults and infants (most sensitive population).

A total margin of exposure (Total MOE) approach was applied to aggregate across three-long term scenarios by combining routinely expected exposure pathways as follows (see Section 3.4.2 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)):

- **Aggregate Exposure Scenario 1 (Worker + Drinking Water + Fish Ingestion [Adult, 21+ Years]):** Workplace inhalation (HHCB dust during compounding/converting) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 3.3.3.1).
- **Aggregate Exposure Scenario 2 (Consumer + Drinking Water + Fish Ingestion [Adults, 21+ Years]):** Consumer inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 3.3.3.1).
- **Aggregate Exposure Scenario 3 (Consumer [Infants, <1 Year] + Drinking Water):** Consumer (infant) inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water.

For Scenarios 1 and 2, exposure estimates were provided only for adults (21+ years). Scenario 3 focused exclusively on infants (<1 year) to address exposures in PESS. For fish ingestion in Scenarios 1 and 2, subsistence fisher intake rates were used to represent upper-bound exposures.

Aggregate Exposure Scenario 1 represents adult (21+ years) with workplace inhalation exposure to HHCB dust during plastic compounding/converting, combined with oral ingestion from HHCB in drinking water and fish (Section 3.3.3.1). ADDs for this scenario are presented in Table 3-6. Upper-bound estimates were used to construct aggregate exposure scenarios to be protective and illustrate potential combined exposures but may not reflect typical conditions or exposures nationwide.

**Table 3-6. Aggregate (Adult Worker + Drinking Water + Fish Ingestion) Exposure Scenario 1 Dose Estimates (21+ Years)** [a]

| Exposed Population | Exposure Pathway and Source | ADD (mg/kg-day) |
|---|---|---|
| Occupational | Inhaling HHCB dust during plastic compounding or converting | 7.80E−02 |
| General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (95th percentile [P95] POTW receiving water concentration scenario with 92% removal efficiency at POTW – assuming no further removal from drinking water treatment) | 2.87E−03 |
| Subsistence Fisher | Ingesting fish containing HHCB (Combined consumer plus commercial down-the-drain based on P95 POTW release, fish tissue concentrations derived from KABAM subsistence fishing ingestion rate) | 1.51E−02 |
| [a] Adapted from Table 3-7 of the HHCB Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). | | |

Aggregate Exposure Scenario 2 represents adult (21+ years) residential inhalation (HHCB mist from a continuous action air freshener) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for general population exposure; see Section 3.3.3.1). Results for Aggregate Exposure Scenario 2 are presented in Table 3-7.

**Table 3-7. Aggregate (Adult Consumer [21+ Years] + Drinking Water + Mist Inhalation) Exposure Scenario 2 Dose Estimates**[a]

| Exposed Population | Exposure Pathway and Source | ADD (mg/kg-day) |
|---|---|---|
| Consumer | Inhaling HHCB mist from a continuous action air freshener | 1.99E−04 |
| General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (P95 POTW receiving water concentration scenario with 92% removal efficiency at POTW – assuming no further removal from drinking water treatment) | 2.87E−03 |
| Subsistence Fisher | Ingesting fish containing HHCB (Combined consumer plus commercial down-the-drain based on P95 POTW release, fish tissue concentrations derived from KABAM, subsistence fishing ingestion rate) | 1.51E−02 |
| [a] Adapted from Table 3-8 of the HHCB Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). | | |

Aggregate Exposure Scenario 3 represents infant (<1 year) residential inhalation (HHCB mist from a continuous action air freshener) combined with oral ingestion from HHCB in drinking water (combined down-the-drain release scenario for general population exposure; see Section 3.3.3.1). Upper-bound estimates were used to construct the aggregate exposure scenario to be protective of most infants (<1 year). Results for Aggregate Exposure Scenario 3 are presented in Table 3-8.

**Table 3-8. Aggregate (Infant Consumer [<1 Year] + Drinking Water + Mist Inhalation) Exposure Scenario 3 Dose Estimates[a]**

| Exposed Population | Exposure Pathway and Source | ADD (mg/kg-day) |
|---|---|---|
| Consumer | Inhaling HHCB mist from a continuous action air freshener | 1.27E−03 |
| General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (P95 POTW receiving water concentration scenario with 92% removal efficiency at POTW—assuming no further removal from drinking water treatment) | 5.95E−04 |

[a] Adapted from Table 3-9 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x).

The aggregate exposure assessment relies upon the analyses, including associated strengths and limitations, previously presented for workers, consumers, and the general population in Sections 3.3.1, 3.3.2, and 3.3.3, respectively.

As noted in Section 2.4 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x), industrial releases are excluded from this aggregate analysis because discharges to POTWs are negligible; therefore, any downstream discharge—and associated human exposure via drinking water or fish—would be minimal. Dermal exposure is also excluded because it is not expected to be hazardous (See Section 1.6 of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)). HHCB's lipophilicity (Fontal et al., 2016; Ramirez et al., 2010) promotes retention on or within the skin, consistent with its role as a fragrance fixative (Homem et al., 2015; Correia et al., 2013), resulting in minimal systemic absorption (See detailed summary of dermal absorption literature in Appendix C of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)).

For aggregate scenarios 1 and 2, EPA used the subsistence fish ingestion rate—rather than the higher tribal rate or the lower general-population 90th-percentile rate—to better represent potential aggregate exposures for most people in the United States. Based on weight of scientific evidence, there is moderate-to-robust confidence that the modeled aggregate exposures reflect high-end inhalation and oral exposures to HHCB across multiple COUs. The aggregate exposure scenarios are based on upper bound assumptions (*e.g.,* highest inhalation exposure source, P95 POTW scenario, highest drinking water and fish ingestion estimates) in the approach that may result in an over estimation of most common aggregate exposures to TSCA COUs, which leads EPA to this conclusion.

Sentinel exposures—plausible upper bound across related exposure categories—are already incorporated throughout this assessment using screening-level or high-end exposure scenarios with conservative inputs and upper-end output. Therefore, no additional sentinel exposure analysis is needed in this assessment.

## 3.4 Human Health Risk Characterization

### 3.4.1 Risk Assessment Approach

Non-cancer risk estimates were developed for occupational, consumer, and general population exposures include aggregate for intermediate and chronic durations. Risk estimates in this assessment are based on hazard information in Section 3.1 (summarized from the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)) and exposure estimates in Section 3.3 (summarized from the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)).

Risks were not estimated for acute exposures because it was determined that it is unlikely any adverse effects will result following a single exposure to HHCB at concentrations relevant to human exposures (Section 2.4.2 in the Draft Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)). Dermal risk estimates were not calculated because HHCB is not expected to be hazardous at relevant doses (Section 2.3 in the Draft Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)). Cancer risks were not estimated as there are no cancer bioassays available for HHCB, and evaluation using the ReCAAP weight-of-evidence framework indicates this absence does not introduce significant uncertainty in the risk characterization (Section 2.5 in the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)). Table 3-9 summarizes the exposure scenarios, populations, and human health hazard values used for risk estimation.

**Table 3-9. Exposure Scenarios, Populations of Interest, and Hazard Values Used**

| | |
|---|---|
| **Population of Interest and Exposure Scenario** | **Workers**<br>Male and female adults (21+ years old; body weight of 80 kg);<br>Females of reproductive age (16 to <21 at body weight of 65.9) (for further details including an average of females of reproductive age 16 to <50 see (U.S. EPA, 2026ab));<br>Directly working with HHCB under light activity (breathing rate of 1.25 $m^3$/h);<br><u>Exposure Duration and Frequencies</u><br>• *Intermediate* – 8 hours per workday for up to 22 days per 30-day period<br>• *Chronic* – 8 hours per workday for up to 250 days per year for 31 or 40 working years<br><u>Exposure Routes</u><br>Inhalation |
| | **Occupational Non-Users**<br>Not separately assessed for this risk evaluation; ONU exposure is expected to be similar or lower than worker exposures. |
| | **Consumers**<br>Infants (<1 year), toddlers (1–2 years), preschoolers (2–5 years), middle childhood (6–10 years), young teens (11–15 years), teenagers (16–20 years) [a] and adults (21+ years) [a] exposed to HHCB through product use (for further details see (U.S. EPA, 2026ab))<br><u>Exposure Durations</u><br>• *Chronic* – 365 days per year, continuously<br><u>Exposure Routes</u><br>Inhalation |
| | **General Population**<br>Male and female infants, children, youth, and adults exposed to HHCB through drinking water and fish ingestion (for further details see Draft General Population Surface Water Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB) (U.S. EPA, 2026w))<br><u>Exposure Durations</u><br>• *Chronic* – Exposed to DCHP continuously for up to 78 years<br><u>Exposure Routes</u><br>Oral (consumption of fish) |
| **Health Effects, Hazard Values, and Benchmarks** | **Non-Cancer Intermediate/Chronic Value**<br>Sensitive health effect: Developmental toxicity (*i.e.,* decreased offspring bodyweight) (for further details see (U.S. EPA, 2026y))<br>HEC Daily, continuous = 38.6 $mg/m^3$ (3.65 ppm)<br>HED Daily = 7.09 mg/kg-day<br>Total UF (benchmark MOE) = 30 ($UF_A$ = 3; $UF_H$ = 10) |

HEC = human equivalent concentration; HED = human equivalent dose; MOE = margin of exposure; UF = uncertainty factor
[a] EPA estimated risks for these populations; however, only risk estimates for the most exposed/sensitive populations are presented in this document.

#### 3.4.1.1 Non-Cancer Risk Calculations

An MOE approach was used to identify potential non-cancer risks. The MOE is the ratio of the non-cancer hazard value (or point of departure (POD)) divided by a human exposure dose. The chronic MOEs for non-cancer inhalation risks were calculated using Equation 3-1.

**Equation 3-1. Margin of Exposure Calculation**

$$MOE = \frac{Non - cancer\ Hazard\ Value\ (POD)}{Human\ Exposure}$$

Where:

| | | |
|---|---|---|
| *MOE* | = | Margin of exposure for acute, short-term, or chronic risk comparison (unitless) |
| *Non-cancer Hazard Value (POD)* | = | Human equivalent concentration (HEC), $\mu g/m^3$ |
| *Human Exposure* | = | Exposure estimate ($\mu g/m^3$) |

MOE risk estimates may be interpreted in relation to benchmark MOEs. Benchmark MOEs are typically the total uncertainty factor for each non-cancer POD. The MOE estimate is interpreted as a human health risk of concern if the MOE estimate is less than the benchmark MOE (*i.e.,* the total uncertainty factor). On the other hand, if the MOE estimate is equal to or exceeds the benchmark MOE, then it is interpreted there is no human health risk of concern. Typically, the larger the MOE, the more unlikely it is that a non-cancer adverse effect occurs relative to the benchmark. For purposes of the screening-level analysis, based on the highly conservative exposure scenarios evaluated in this assessment, if the MOE is equal to or greater than the benchmark MOE the exposure pathway is not analyzed further. When determining whether a chemical substance presents unreasonable risk to human health or the environment, calculated risk estimates are not "bright-line" indicators of unreasonable risk, and EPA has the discretion to consider other risk-related factors in addition to risks identified in the risk characterization.

### 3.4.2 Risk Estimates for Occupational Exposures

Intermediate and chronic risks for workers from inhalation (Table 3-10) resulted in MOEs much greater than the benchmark of 30 for all scenarios; therefore, no risk is expected. Impacts of PPE (*i.e.,* respirators) were not included in the table. Calculations including consideration of alternative bodyweights and PPE impacts are provided in the *Draft Occupational Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ab).

**Table 3-10. Intermediate and Chronic Occupational Risk Estimates for Workers**

| Highest Exposure Scenario | COUs | Worker Type | Intermediate Inhalation Risks (Benchmark = 30) | | Chronic Inhalation Risks (Benchmark = 30) | |
|---|---|---|---|---|---|---|
| | | | 50th Percentile | 95th Percentile or Regulatory Limit | 50th Percentile | 95th Percentile or Regulatory Limit |
| Formulation of Fragrance Oils | Processing – Incorporation into formulation, mixture or reaction product – Odor agent in: All other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; other: Fragrance mixtures and fragrance raw materials | Average adult | 38,101 | 4,198 | 40,794 | 4,495 |
| | | Women between 16–21 years (most sensitive group) | 31,386 | 3,458 | 33,604 | 3,703 |
| Plastic Compounding/ Converting | Processing – incorporation into articles – Odor agent in: Plastics material and resin manufacturing | Average adult | 430 | 103 | 460 | 110 |
| | | Women age between 16–21 years (most sensitive group) | 354 | 85 | 379 | 91 |

The results reflect two occupational inhalation exposure scenarios (Section 3.3.1) elected to represent the highest exposure potential for their respective exposure pathway (vapor and dust). Mist inhalation may occur, but the conservative consumer exposure scenario is expected to be protective of this pathway (Section 3.3.2) and no risk was identified (Section 3.4.3).

Worker vapor inhalation exposure was estimated using standard EPA/OPPT vapor models (EPA/OPPT Mass Balance Inhalation Model) (U.S. EPA, 2015). Activity-specific concentrations were modeled for unloading neat HHCB at 75°C (the dominant driver) as well as container and equipment cleaning, sampling, and packaging. This is expected to be a high-end vapor inhalation exposure scenario across all COUs. Risk estimates assume 8 exposure hours per day and 250 exposure days per year; activity concentrations were combined to an 8-hour time-weighted average.

High-end intermediate and chronic inhalation MOEs for average adult workers and female workers between the ages of 16 and 21 ranged from 3,458 to 4,495; the central tendency MOEs ranged from 31,386 to 40,794. Even the lowest MOE exceeds the benchmark MOE of 30 by more than 100-fold, indicating no risk of concern for workers via vapor inhalation.

For dust exposure, inhalation exposure during handling and transport of plastic pellets containing HHCB was estimated. Dust generated by agitation of plastic pellets during transport that may become airborne during unloading of plastic pellets. The inhalation exposure was estimated using surrogate dust monitoring data from OSHA chemical exposure health data for PNOR (U.S. EPA, 2021). The central tendency used the 50th percentile PNOR measurements for the chemical manufacturing industry

(NAICS sector 325), selected based on the NAICS code reported by plastic product manufacturers in the 2023 TRI dataset (U.S. EPA, 2023c). As the 95th percentile of the monitoring data exceeds the regulatory limit for PNOR, the regulatory limit was used to represent a high-end exposure estimate. As further discussed in Section 3.3.1, the approach uses the model with the maximum concentration of HHCB (5% w/w) in finished plastic articles. The risk estimates assume 8 hours per day and 250 days per year based on a typical worker schedule. Dust inhalation exposures estimates for handling and transport HHCB-containing plastic pellets are assumed to be protective of other dust inhalation scenarios, including other exposed populations.

The exposure estimates result in MOEs for high-end intermediate and chronic inhalation risks ranged from 85 to 110 for average adult workers and female workers between the ages of 16 and 21. The central tendency MOEs for the same population and exposure scenarios ranged from 354 to 460. At the lowest MOE, estimated risks are still more than two-fold higher than the benchmark MOE. Therefore, EPA determined dust inhalation is not a pathway or route of concern for worker exposures or associated risks.

##### 3.4.2.1 Overall Confidence in Worker Risks

Given MOEs well above the benchmark, there is robust confidence that workers face no human health risk across all TSCA COUs. Confidence in the precision of the underlying exposure estimates is moderate, but there is high confidence that the estimates are suitable for screening.

### 3.4.3 Risk Estimates for Consumer Exposures

Estimated long-term or chronic risks associated with consumer TSCA COUs are presented in Table 3-11. MOEs ranged from 5,583 to 35,600 and were well above the benchmark of 30. These risks are based on modeled consumer exposure from 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, 2026x) and summarized in Section 3.3.2.

**Table 3-11. Chronic Consumer Inhalation Risk Calculations**

| Condition of Use Subcategory | Consumer Population | Chronic Non-Cancer Risk (MOE) Benchmark = 30 |
|---|---|---|
| Continuous action air fresheners | Adult (21+ years) | 35,600 |
| | Youth (16–20 years) | 30,200 |
| | Youth (11–15 years) | 24,000 |
| | Child (6–10 years) | 15,897 |
| | Child (3–5 years) | 9,304 |
| | Infant (1–2 years) | 5,764 |
| | Infant (<1 year) | 5,583 |

Chronic consumer inhalation risks are presented for all age groups because consumers and bystanders may be exposed to spray from continuous-action air fresheners. The risk estimates were based on high-end modeled air concentrations over 365 days using TSCA COU-specific frequency/duration assumptions and the developmental-effects POD from the rat EOGRT study (IFF, 2021). The MOEs indicate no risk of concern under a screening scenario of a continuous-action air freshener dispensing atomized HHCB in a small room (15 $m^3$; *e.g.,* bathroom, bedroom, dorm room) every 15 minutes, operating 24/7 (representing continuous presence or movement among similarly treated spaces), with 107 $m^3$/h ventilation and a well-mixed air assumption (Chase Products, 2025). All risk estimates are provided in the *Draft Consumer Chronic Inhalation Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026e).

***Consumer Risk Weight of Scientific Evidence***

Given that MOEs for consumer exposures are at least 186 times above the benchmark and that estimated exposures were represented by upper-bound conditions based on conservative assumptions (*e.g.,* small room, 24 hours/day occupancy, and estimation using highest weight fraction), there is robust confidence that consumers face no human health risk across all TSCA COUs.

### 3.4.4 Risk Estimates for General Population Exposures

Risk to the general population was estimated for the surface water pathway, including exposure via fish consumption, and drinking water.

#### 3.4.4.1 Fish Ingestion

Fish consumption risk estimates are presented in Table 3-12. Fish consumption risk resulted in MOEs greater than the benchmark of 30 under high-end assumptions (P95 POTW receiving-water concentrations). MOEs ranged from 6,720 at the general population 90th-percentile ingestion rate to 39 at the current tribal high-end ingestion rate. The high-end modeling and monitored surface water concentrations were applied to assess upper-bound risk under protective assumptions included in the analyses described in Section 2.3.2 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, 2026x). Results are provided for the general population, subsistence fishers, and tribal populations.

**Table 3-12. General Population Risk Estimates for Fish Ingestion**

| Scenario | Surface Water Concentration (SWC) (µg/L) | Fish Tissue Concentration (mg/kg) | MOE, Chronic (Adults) (Benchmark = 30) | | | |
|---|---|---|---|---|---|---|
| | | | General Population 90th Percentile IR | Subsistence Fisher IR | Tribal, Current Central Tendency IR | Tribal, Current High-End IR |
| Consumer Plus Commercial Combined DTD (KABAM Method) | 25.4[a] (P95 POTW) | 8.5 Whole fish | 6,720 | 238 | 157 | 39 |
| Highest monitored fish tissue (common carp, whole fish) | N/A | 2.10 Whole fish | 9,410 | 333 | 220 | 54 |

DTD = down-the-drain; IR = ingestion rate; KABAM = KOW (based) Aquatic BioAccumulation Model
[a] A 92% removal efficiency for HHCB is applied to these modeled releases.

High-end modeled/monitored surface-water concentrations were used to estimate upper-bound fish-tissue levels. POTW percentiles reflect contributing population, HHCB loading, treatment removal, and receiving-water characteristics (derived from the 2022 CWNS). The 95th-percentile POTW concentration was used for modeling, representing an upper-end receiving-water condition expected to be exceeded at only approximately 5% of POTWs nationwide. Fish tissue concentrations were modeled using KABAM to simulate uptake from the modeled environmental media concentrations. Further details on down-the-drain modeling, environmental media concentrations, and fish tissue modeling are provided in the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s) and the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x).

Daily fish-ingestion rates used were: 1.78 g/kg (subsistence fisher), 2.7 g/kg (tribal mean), and 10.9 g/kg (tribal high-end). General population ingestion rates are lower than the subsistence fisher rate, resulting in lower exposures. Ingestion rates are based on NHANES[4] data and published literature summarized in the *Exposure Factors Handbook* (U.S. EPA (2011a)). General-population rates represent the U.S. population, while tribal rates come from surveys of specific communities and span the Handbook. Full inputs and calculations are provided in the *Draft Fish Ingestion Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026v).

As discussed in Section 3.3.3, the MOEs and fish tissue concentrations reported in Table 3-12 (aside from the highest monitored fish tissue concentration) are calculated from estimated fish tissue concentrations derived from surface water concentrations. Confidence in the high-end POTW surface-water concentrations at the point of discharge is moderate-to-robust. Comparable POTW scenarios with greater receiving water flow, lower contributing population, or both would yield lower modeled concentrations while ambient concentrations would decline further in waters not directly receiving effluent or farther downstream from the outfall due to dilution and sorption to organic matter and sediments.

Precision in the exposure estimates decreases as additional variability is introduced (*e.g.,* fish exposure, ingestion rates, harvest locations). Selecting high-end values across input distributions produces a protective upper-bound scenario—each condition is plausible, but the combination is less likely and not expected broadly. When high-end fish exposure and ingestion are combined with the P95 POTW scenario, the resulting exposure exceeds the 95th percentile of the potential exposure distribution. These concentrations are therefore high-end and serve as screening values. Refined fish-tissue assessment supports moderate confidence that, even under protective assumptions (*e.g.,* chronic harvest near a high-end outfall location), fish-ingestion MOEs are not expected to fall below the benchmark of 30.

The highest monitored fish-tissue concentration (2.1 mg/kg) was from a sample collected near a high-end (P95) POTW outfall. This monitored fish tissue concentration near a known high-end POTW outfall reflects the potential for variable exposure concentrations and uptake in fish, even when collected in proximity to high water column concentrations. For example, while fish tissue modeling for an equivalent scenario would predict a higher concentration in fish, that modeling includes the assumption that the fish remain in water with that concentration of HHCB long enough to reach equilibrium, while the fish collected in the study are more likely to have resided in waters of varying lower HHCB concentrations before ultimately being caught near the POTW outfall. In addition to the conservatism built into the modeling through this assumption, the environmental modeling conducted in this assessment includes only exposure from HHCB originating from the COUs described, whereas

[4] National Health and Nutrition Examination Survey (accessed March 22, 2026), a continuous, nationally representative survey run by CDC's National Center for Health Statistics (NCHS).

environmental monitoring data may include HHCB from other sources not regulated by TSCA, indicating that the model estimates of fish tissue that exceed monitored fish tissue concentrations are sufficiently protective to screen for risk.

The scenario described by the high-end fish ingestion exposure above (the P95 POTW scenario with the high-end tribal ingestion rate) relies on multiple coinciding factors. The concentration in the receiving water body from the POTW effluent is a high-end scenario, based on a harmonic mean flow, which is only expected to be exceeded by up to 5% of the POTW locations in the country. The fish consumed would have been exposed to a consistent high concentration for at least the approximately 20 days required to achieve a steady state concentration in the fish tissue. An adult person with a body weight of 80 kg would be consuming over 800 g of fish per day at the described concentration from the described site of POTW effluent, for multiple days to achieve intermediate or chronic exposure.

Shellfish ingestion risk is expected to be lower than fish-consumption risk because commonly consumed shellfish are seldom available near the freshwater POTW sites evaluated, typical marine/estuarine harvest areas have lower HHCB exposure than fish near POTW effluent, and human shellfish ingestion rates are generally lower than those assessed for fish ingestion (U.S. EPA, 2011a). "Shellfish" includes bivalves and crustaceans with diets primarily featuring marine/estuarine species, with freshwater taxa (*e.g.,* crayfish) less common. Accordingly, there is robust confidence that shellfish ingestion risks are lower than general population fish consumption risks; MOEs are expected to be far greater than the benchmark.

#### 3.4.4.2 Drinking Water

The general population exposure assessment for drinking water ingestion resulted in MOEs well above the benchmark of 30, under the high-end model assumptions for combined commercial plus consumer down-the-drain releases and monitored surface water concentrations (Table 3-13).

**Table 3-13. General Population Risk Estimates for Drinking Water Ingestion**

| Scenario | Harmonic Mean Concentration (µg/L) | 30Q5 Concentration (µg/L) | Infant (Birth to 1 year) Acute MOE (Benchmark = 30) | Infant (Birth to 1 year) Chronic MOE (Benchmark = 30) |
|---|---|---|---|---|
| Combined Consumer Plus Commercial DTD (P95) | 21.2 | 25.4 | 1,980 | 11,900 |
| High from Monitoring | 25.5 | 25.5 | 1,970 | 9,900 |
| P95 = 95th percentile; 30Q5 = lowest 30-day average flow that occurs (on average) once every 5 years; MOE = margin of exposure | | | | |

For the most sensitive endpoint, risk for an infant less than one year old, the lowest MOE resulting from high-end surface water concentrations was 1,970. Further evaluation of incidental ingestion or from recreation activities was not pursued, because the drinking water exposure scenario is protective of these incidental scenarios which result in lower general population doses. Results reflect modeled and monitored inputs and assume no drinking-water treatment removal, although treatment is expected to substantially reduce HHCB in source water, similar to the efficiencies observed with wastewater treatment (Section 1.3.2). Source water is assumed to be at or near the POTW outfall; concentrations downstream, where a community water system intake may be located, are likely further reduced by sorption to organic matter, including sediments, in aquatic environments. Scenarios were selected to represent the highest exposure potential.

Given MOEs well above the benchmark, there is robust confidence that the general population faces no human-health risk from drinking-water exposure to HHCB across all TSCA COUs. Confidence in the precision of the underlying exposure estimates is slight-to-moderate due to the protective factors biasing these estimates higher, but there is robust confidence that they represent upper bound values suitable for screening.

#### 3.4.4.3 Human Milk

EPA did not quantitatively estimate risk to infants via exposure to HHCB in human milk. Specifically, the Agency is unable to derive a hazard value in terms of an infant dose that is suitable for use alongside the available biomonitoring data to estimate risk for infants due to lactational exposure. This is because the relevant hazard value for HHCB, which is based on decreased offspring bodyweight during an exposure window that includes lactation, is expressed in terms of the maternal (rather than infant) dose.

Furthermore, EPA has concluded that the risk estimates for pregnant women and women of reproductive age provided in this risk assessment are protective of infant exposures to HHCB via human milk. This is because infant exposure via human milk depends on maternal exposure to HHCB, and because the human health hazard value used to calculate risks to pregnant women and women of reproductive age in this assessment is based on effects in offspring that were exposed during a window including lactation in the associated EOGRT study (IFF, 2021).

### 3.4.5 Risk Characterization for Potentially Exposed or Susceptible Subpopulations

For the HHCB draft risk evaluation, EPA considered information that could support increased exposure or biological susceptibility compared to the general population. EPA was able to incorporate considerations for multiple PESS factors into risk estimates. EPA may have considered these using exposure factors, uncertainty factors, and PESS group-specific hazard or exposure data as detailed below. For other factors, EPA was either unable to identify relevant chemical-specific data or could not adequately quantify their contribution. These are addressed in detail in the corresponding hazard and exposure assessment support documents.

Available data indicate that certain groups or lifestages have higher HHCB exposure – workers; frequent users of products/articles with high HHCB content, and infants, children, adolescents with higher intake per body weight (see Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x)). Some lifestages may also be more susceptible to HHCB health effects. Developmental exposure in an EOGRT study decreased offspring body weight in rats ((IFF, 2021); see also EPA's Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y)). Accordingly, females of reproductive age, pregnant women, infants, and children are treated susceptible subpopulations. PESS considerations are incorporated in the draft HHCB risk evaluation as follows:

- **Workers:** OESs were evaluated, including high-end scenarios for females of reproductive age (susceptible subpopulation) and average adult workers.
- **Consumers:** Upper-bound plausible scenarios were evaluated across all age groups; infants and females of reproductive age were treated as susceptible subpopulations.
- **General Population:** High-end scenarios were evaluated for infants and children (susceptible subpopulations) due to higher intake per body weight relative to adults, including women of reproductive age.
- **Fish Ingestion:** Exposure via fish consumption was evaluated for subsistence fishers and tribal populations.

- **Aggregation:** High-end inhalation and oral exposures were aggregated for adult females across occupational and general-population pathways; consumer inhalation and oral exposures across COUs were aggregated for infants and females of reproductive age.
- **Human Variability:** An uncertainty factor ($UF_H$) of 10 was applied to account for interindividual variability, consistent with the Risk Assessment Forum guidance (U.S. EPA, 2002).
- **Protectiveness of Hazard Value:** The non-cancer POD used to estimate risks is protective of sensitive lifestages (females of reproductive age, infants, and children) and developmental exposures (including gestation and lactation). This is because the human health hazard value used to calculate risks is based on effects (decreased bodyweight) in animals that were exposed during gestation and lactation.

### 3.4.6 Risk Characterization for Aggregate and Sentinel Exposures

The chronic, non-cancer, aggregate MOE estimates were 86, 390, and 3,802 for *Aggregate Scenarios 1 to 3*, respectively; all of which exceeded a benchmark of 30 (see Table 3-14). This indicates that the aggregate exposure is lower than when compared to the benchmark MOE. Lower MOE compared to the benchmark values indicate greater risks. Across *Aggregate Scenarios 1 to 3*, risk estimates are driven by fish ingestion, followed by occupational exposures; consumer exposures contribute to a lesser extent. These aggregates are plausible upper-bound scenarios for the U.S. population, not the most likely individual exposures, and rely on high-end inputs. The scenarios combine high-end assumptions across pathways to represent potential TSCA-based aggregate HHCB exposures. For a description of what each aggregate exposure scenario represents and the associate risks calculated see Table 3-14. All risk estimates including for all exposure scenarios evaluated are provided in the *Draft Aggregate Chronic Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta [γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026b).

**Table 3-14. Summary of Aggregate Non-Cancer Risk Estimates**

| Aggregate Scenario ID | Aggregate Exposure Scenario | Exposed Population | Exposure Pathway and Source | Chronic Average Daily Dose Per Individual Scenario (mg/kg/day) | Chronic Non-Cancer MOE per Aggregate Scenario (Benchmark = 30) | Chronic Non-Cancer Risk (Total MOE[a]) (Benchmark = 30) |
|---|---|---|---|---|---|---|
| *Aggregate Scenario 1* | Adult (21+ years) worker inhalation (HHCB dust during compounding/ converting) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure). | Occupational | Inhaling HHCB dust during plastic compounding or converting | 7.80E−02 | 91 | 74 |
| | | General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (95th percentile (P95) POTW receiving water concentration scenario with 92% removal efficiency at POTW – assuming no further removal from drinking water treatment) | 2.87E−03 | 2,470 | |
| | | Subsistence Fisher | Ingesting fish containing HHCB (Combined consumer plus commercial down-the-drain releases from P95 POTW, fish tissue concentrations derived from KABAM, subsistence fishing ingestion rate) | 1.51E−02 | 470 | |
| *Aggregate Scenario 2* | Adult (21+ years) consumer inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure). | Consumer | Inhaling HHCB mist from a continuous action air freshener | 1.99E−04 | 35,628 | 390 |
| | | General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (P95 POTW receiving water concentration scenario with 92% removal efficiency at POTW – assuming no further removal from drinking water treatment) | 2.87E−03 | 2,470 | |
| | | Subsistence Fisher | Ingesting fish containing HHCB (Combined consumer plus commercial down-the-drain releases from P95 POTW, fish tissue concentrations derived from KABAM Model, subsistence fishing ingestion rate) | 1.51E−02 | 470 | |

| Aggregate Scenario ID | Aggregate Exposure Scenario | Exposed Population | Exposure Pathway and Source | Chronic Average Daily Dose Per Individual Scenario (mg/kg/day) | Chronic Non-Cancer MOE per Aggregate Scenario (Benchmark = 30) | Chronic Non-Cancer Risk (Total MOE[a]) (Benchmark = 30) |
|---|---|---|---|---|---|---|
| *Aggregate Scenario 3* | Consumer (infant, <1 year) inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water. | Consumer | Inhaling HHCB mist from a continuous action air freshener | 1.27E−03 | 5,583 | 3,802 |
| | | General Population | Consuming drinking water containing HHCB from combined commercial plus consumer down-the-drain releases to surface water (P95 POTW receiving water concentration scenario with 92% removal efficiency at POTW – assuming no further removal from drinking water treatment) | 5.95E−04 | 11,916 | |
| [a] Aggregate risks were calculated using total margin of exposure (MOE) = 1 ÷ ([1 ÷ inhalation MOE] + [1 ÷ oral MOE]) | | | | | | |

EPA estimated the aggregate risks associated with long-term exposure to HHCB. For this analysis, the Agency relied on inhalation and oral exposure estimates for consumers, workers, general population (subsistence fishers), and tribal population as presented 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, 2026x) and summarized in Section 3.3.4. Three aggregate scenarios were considered for HHCB. These aggregate estimates were calculated for infants (<1 year; the most sensitive age group) and adults (≥21 years) because their exposures were evaluated across most exposure scenarios in this draft risk evaluation. However, younger females of reproductive age were not assessed for drinking water and fish ingestion.

For *Aggregate Scenarios 1 and 2*, EPA used the subsistence fisher ingestion rate to identify an upper bound estimate that is protective of the majority of people in the general population. Across *Aggregate Scenarios 1 to 3*, risk estimates are primarily driven by occupational exposures, followed by fish ingestion, while consumer exposures contribute to a lesser extent. All chronic risk estimates that have been incorporated into *Aggregate Scenarios 1 to 3* were calculated using high-end concentrations for a 365-day period based on a set of high-end model input assumptions and TSCA COU-specific assumptions about potential exposure durations and frequencies. These aggregates are plausible upper-bound scenarios for the U.S. population, not the most likely individual exposures, and rely on high-end inputs. For a description of what each aggregate exposure scenario represents and the associate risks calculated see Table 3-14.

The chronic non-cancer risk estimates were based on the chronic POD for developmental effects reported in controlled rodent exposure studies. Aggregate risks were calculated using the Total MOE (equal to 1 ÷ [1 ÷ inhalation MOE] + [1 ÷ oral MOE]) approach to account for differences in uncertainty factors (as appropriate) and to ensure that the toxicological effects across all relevant routes are consistent and additive.

# 4 UNREASONABLE RISK DETERMINATION

TSCA section 6(b)(4) requires EPA to conduct a risk evaluation to determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other non-risk factors, including an unreasonable risk to PESS identified by EPA as relevant to this risk evaluation, under the COUs.

EPA has preliminarily determined that HHCB does not present an unreasonable risk of injury to human health or the environment under any of the 22 COUs. This preliminary unreasonable risk determination is based on the information in previous sections of this risk evaluation, the appendices, TSDs, and supplemental files of this draft risk evaluation (Appendix C). This preliminary unreasonable risk determination and the underlying evaluation are consistent with the best available science (TSCA section 26(h)) and based on the weight of scientific evidence (TSCA section 26(i)).

As noted in the Executive Summary, HHCB is primarily used as a synthetic musk compound widely used as a fragrance. It is utilized in household products such as detergents, cleaners, and air fresheners. HHCB is also a key ingredient in non-TSCA uses including perfumes, cosmetics, and personal care products due to its long-lasting scent properties. Workers may be exposed to HHCB through dust, mist, or vapor when making these products (Section 3.3.1). Consumers may be exposed to HHCB through dust, mist, or vapor when products containing HHCB are used as intended such as cleaning a counter, placing an air freshener in a bathroom, or doing laundry (Section 3.2.2). The general population may be exposed to HHCB from consuming drinking water (surface water sourced) or fish containing HHCB as well as through incidental contact and ingestion while recreating in waters containing HHCB (Section 3.2.3). HHCB can be released into water through manufacturing of HHCB, but most release sources of HHCB into the environment are through commercial and consumer uses of the fragrance being disposed of down-the-drain after its intended use (Sections 1.4.2 and 3.3).

EPA has preliminarily determined that all 22 COUs identified do not significantly contribute to the unreasonable risk to human health or the environment for HHCB:

- Manufacturing – Domestic manufacture
- Manufacturing – Import
- Processing – Incorporation into formulation, mixture, or reaction product – Odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials
- Processing – Incorporation into articles – Odor agent in plastics material and resin manufacturing
- Processing – Repackaging – Odor agent in all other chemical product and preparation manufacturing
- Processing – Recycling
- Distribution in commerce
- Commercial use – Air care products – Air fresheners for motor vehicles
- Commercial use – Air care products – Continuous action air fresheners
- Commercial use – Air care products – Instant action air fresheners
- Commercial use – Cleaning and furnishing care products – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)

- Commercial use – Laundry and dishwashing products – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash)
- Commercial use – Plastic and rubber articles not covered elsewhere – Plastic and rubber articles
- Commercial use – Other use laboratory chemicals – Laboratory chemicals
- Consumer use – Air care products – Air fresheners for motor vehicles
- Consumer use – Air care products – Continuous action air fresheners
- Consumer use – Air care products – Instant action air fresheners
- Consumer use – Cleaning and furnishing care products – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)
- Consumer use – Laundry and dishwashing products – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/ granule); Dishwashing detergent liquid (hand-wash)
- Consumer use – Plastic and rubber articles not covered elsewhere – Plastic and rubber articles
- Consumer use – Chemical substances in treatment products – Ion exchangers; Liquid water treatment products; Solid powder water treatment products
- Disposal

For some COUs, the Agency has limited reasonably available information to derive risk estimates (such as MOEs or RQs) to support a determination of whether the COU contributes to unreasonable risk of injury to human health or the environment. In such cases, EPA integrates reasonably available information (*e.g.* physical and chemistry properties, available monitoring data) into a risk characterization using a weight of evidence approach and professional judgement to support conclusions. The risk characterizations of COUs that EPA evaluated qualitatively present what EPA expects given the weight of scientific evidence. These COUs include Distribution in commerce and releases associated with Consumer uses.

The unreasonable risk determination is informed by science and in making a finding of "presents unreasonable risk," EPA considers risk-related factors beyond exceedance of benchmarks. Risk-related factors include the type of health effect under consideration, the reversibility of the health effect being evaluated, exposure-related considerations (*e.g.,* duration, magnitude, frequency of exposure), or population exposed—particularly populations with greater exposure or greater susceptibility (PESS), and the confidence in the information used to inform the hazard and exposure values. EPA also considers, where relevant, the Agency's analyses of aggregate exposures. Aggregate exposure analyses consider effects on populations or receptors that are exposed to HHCB via multiple routes for human health (*e.g.,* ingestion and inhalation) and through environmental releases through down-the-drain consumer and commercial uses.

For COUs evaluated quantitatively, as described in the risk characterization, EPA based the risk determination on the risk estimate that best represents the COU. Additionally, the Agency describes the strength of the scientific evidence supporting the human health and environmental assessments as robust, moderate, or slight. Robust confidence suggests thorough understanding of the scientific evidence and uncertainties, and the supporting weight of scientific evidence outweighs the uncertainties to the point where it is unlikely that the uncertainties could have a significant effect on the risk estimates. Moderate confidence suggests some understanding of the scientific evidence and uncertainties, and the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize risk. Slight confidence is assigned when the weight of scientific evidence may not be adequate to characterize the risk, and when the Agency is making the best scientific assessment possible in the absence of complete information. The designation of slight-to-moderate confidence suggests that some aspects of the analysis are reasonably adequate but that other aspects are not adequate or sufficiently understood to characterize the exposure.

## 4.1 Unreasonable Risk to the Environment

EPA estimated and predicted environmental concentrations of HHCB from industrial and down-the-drain releases from commercial and consumer uses into surface water and sediment, biosolid applications to soil, and bioconcentration in aquatic animals to terrestrial organisms. The Agency expects HHCB environmental exposure pathways in surface water and sediment after discharge from wastewater treatment facilities and in soil after application of biosolids. Based on the environmental risk assessment, EPA is preliminarily determining that HHCB does not present an unreasonable risk of injury to the environment due to acute and chronic non-cancer exposures for aquatic and terrestrial species using a quantitative high-end screening approach as well as measured and monitored data.

EPA characterized the environmental risk of HHCB using risk quotients (RQs), which compare the predicted environmental concentration with hazard threshold values. More information about RQs, their interpretation, and use is provided in Section 2.4.1.

### 4.1.1 Populations and Exposures Assessed for the Environment

EPA evaluated the following exposures and populations for the environment resulting from

- acute and chronic non-cancer exposure to aquatic organisms via surface water, including fish swimming in the water column;
- chronic non-cancer exposure to aquatic organisms via sediment, including benthic invertebrates;
- chronic non-cancer exposure to terrestrial organisms via biosolid application to soils for invertebrates and plants and;
- chronic non-cancer exposure to terrestrial organisms via trophic transfer from water and soil for mammals.

For aquatic organisms, surface water and subsequent deposition to aquatic sediment were characterized by comparing the hazard thresholds from exposures due to industrial releases attributable to TSCA COUs and modeled data from generic down-the-drain scenarios from commercial and consumer uses. For down-the-drain scenarios, HHCB is found in liquid soaps, dishwashing detergents, and laundry detergents. These products are eventually disposed of and processed at publicly owned treatment works or wastewater treatment facilities. After processing, treated water is discharged into local waterways of various flow rates and sizes. This compounding nature of collective amounts of HHCB in treated wastewater can be quantified using combined down-the-drain scenarios. More information on this analysis can be found in Section 2.3.

For terrestrial organisms, soil-dwelling invertebrates and plants were modeled for exposures based on the maximum HHCB concentrations found in biosolids that are applied to agricultural fields. A screening-level approach was used to focus on the upper-bound exposure concentrations in terrestrial organisms using the maximum reported HHCB concentration in biosolids. Due to a lack of reasonably available data related to COUs, the maximum reported HHCB concentration in biosolids was used as the upper bound to screening soil exposures and as a result of this screening analysis, no RQ values were developed for each COU. More information on this screening analysis can be found in Section 2.3. Additionally, for terrestrial mammals, HHCB concentrations are found in the food web. Trophic transfer, which is the movement of energy, nutrients, and contaminants from one trophic level or feeding level to the next in an ecosystem, occurs for HHCB concentrations from prey to predator. EPA therefore analyzed two pathways via trophic transfer: (1) aquatic organisms to terrestrial mammals, and (2) invertebrates living in soils applied with biosolids containing HHCB to terrestrial mammals. Furthermore, HHCB containing biosolids from publicly owned treatment works or wastewater treatment facilities can be applied to soils and have the potential to impact soil derived food webs. More information on the trophic transfer analysis can also be found in Section 2.3.

Environmental risk of HHCB in air was assessed qualitatively because the reasonably available evidence indicates that the bioavailability of HHCB in air is expected to be low and there is little evidence of adverse effects on wild organisms. More information on this qualitative assessment can be found in Section 2.3. Additionally, while the land pathway was assessed quantitatively via biosolid application and trophic transfer in soil, landfill disposal for commercial and consumer COUs would not have the potential to leach or be mobile in these waste processing settings because of the physical and chemical properties of HHCB, including the chemical half-life and through photolysis. More information can be found in Section 1.3.1.

In general, EPA has an overall moderate-to-robust confidence in environmental releases for acute and chronic non-cancer exposure assessments for aquatic species—both in the surface water and sediment—as well as terrestrial species measured at the central tendency. For high-end exposures however, the Agency has less confidence in these environmental releases because EPA incorporated multiple levels of conservatism as part of the screening assessment such as high concentrations of HHCB in the water. EPA has moderate-to-robust confidence in the overall risk characterization. Additional information can be found in Section 2.5.

### 4.1.2 Summary of Environmental Effects

EPA has preliminarily determined that all COUs assessed do not significantly contribute to the unreasonable risk of injury to the environment presented by HHCB due to a lack of acute and chronic non-cancer effects to aquatic and terrestrial organisms.

EPA has preliminarily determined that the effects of HHCB to aquatic organisms, including fish and benthic invertebrates from HHCB, do not present an unreasonable risk to the environment.

EPA has preliminarily determined that the effects of HHCB to terrestrial organisms, including soil-dwelling invertebrates and plants via HHCB concentrated biosolids applied to soil, do not present an unreasonable risk to the environment. EPA also has preliminarily determined that the effects to terrestrial organisms, including terrestrial mammals via trophic transfer for the two pathways assessed, do not present an unreasonable risk of injury to the environment.

### 4.1.3 Basis for Unreasonable Risk to the Environment

Based on the draft risk evaluation for HHCB, including the risk estimates, the environmental effects of HHCB, the exposures, physical and chemical properties of HHCB, as well as the consideration of uncertainties, EPA did not identify risk of injury to the environment that would significantly contribute to the unreasonable risk determination for HHCB for any of the aquatic or terrestrial receptors evaluated.

EPA quantitatively evaluated surface water, sediment, biosolid application to soils, and trophic transfer from soil and water pathways. Again, consistent with EPA's determination of unreasonable risk to human health, the RQ is not treated as a "bright-line" and other risk-based factors may be considered (*e.g.,* confidence in the hazard and exposure characterization, duration, magnitude, uncertainty) for purposes of making an unreasonable risk determination.

EPA is preliminarily determining that the following COUs, which were assessed qualitatively, do not significantly contribute to the unreasonable risk presented by HHCB to the environment:

- Commercial and consumer use – Air care products, including air fresheners for motor vehicles, continuous action air fresheners, and instant action air fresheners do not have derived risk estimates because releases are primarily expected to be through landfills after disposal. Additionally, HHCB is not expected to be readily found in ambient air due to volatilization;
- Commercial use – Laboratory chemicals did not have derived risk estimates as no facilities for use as a laboratory chemical were identified in TRI and releases to down-the-drain are expected to be minimal;
- Commercial and Consumer use – Plastic and rubber articles did not have derived risk estimates as these article releases are expected to be disposed of through the landfill;
- Distribution in commerce did not have derived risk estimates as EPA expects HHCB to be transported in sealed containers and no releases are expected;
- Disposal did not have derived risk estimates as EPA expects minimal environmental releases to occur during the disposal of a wide variety of HHCB-incorporated articles and there were no releases reported to surface water.

More information can be found in Section 2.4.

#### 4.1.3.1 Aquatic Species

EPA quantitatively assessed the concentration of concern for aquatic organisms from both measured and modeled surface water and sediment exposures from industrial releases through TRI reports utilizing COU-specific data as well as generic down-the-drain water release scenarios from commercial and consumer uses. Overall, EPA is preliminarily determining that there is no unreasonable risk from HHCB to aquatic species.

For aquatic organisms, EPA assessed both acute and chronic non-cancer exposures via surface water and only chronic non-cancer exposures via sediment. For acute exposures for aquatic organisms via surface water, including fish that swim in the water column, all measured and modeled HHCB concentrations resulted in RQ values that were below the benchmark of 1, preliminarily determining no unreasonable risk. For chronic non-cancer exposures for both aquatic organisms via surface water and sediment, including benthic invertebrates, certain maximum measured concentration values (*e.g.,* 25.5 µg/L surface water concentration) resulted in RQ values above the benchmark of 1. However, for both surface water and sediment exposures, EPA is preliminarily determining that these chronic, high-end concentrations do not contribute to the unreasonable risk because the highest modeled concentration represents scenarios of rarely occuring conditions, such as historically low flow rates paired with high HHCB concentration, and is expected to overestimate risk. For measured concentrations, the slight confidence is a result of the underlying data originating from numerous sources with different sampling methods that are not necessarily attributable to any COU. For modeled concentrations, the moderate confidence is the result of compounding conservative assumptions such as low flow rates, consistent releases, and predictable animal behaviors that are all unrealistic to assume over long periods of time that would lead to chronic exposures. More information on the characterization of these data can be found in Section 2.4.

#### 4.1.3.2 Terrestrial Species

EPA quantitatively assessed the concentration of concern for terrestrial organisms via biosolid application to soils for invertebrates and plants through the use of a screening assessment by comparing hazard thresholds in those organisms to modeled HHCB exposures in soils. EPA also quantitatively assessed chronic non-cancer exposures to terrestrial organisms via trophic transfer from water for mammals using measured and modeled data, including down-the-drain modeled scenarios, as well as through the use of a screening assessment for trophic transfer from soil for mammals. Overall, EPA is preliminarily determining that there is no unreasonable risk from HHCB to terrestrial species.

***Biosolid Application in Soils to Invertebrates and Plants***

EPA assessed chronic non-cancer exposures to terrestrial organisms via biosolid application to soils for invertebrates and plants by comparing the concentration of concern for soil-dwelling invertebrates and plants to modeled exposures in soil based on the HHCB concentrations applied as biosolids to agricultural fields. For both invertebrates and plants, the hazard threshold was not exceeded by any measured HHCB concentrations applied as biosolids in soils, including maximum measured amounts of HHCB. Therefore, for both invertebrate and plants, all calculated RQ values were below the benchmark of 1, preliminarily determining there is no unreasonable risk.

***Trophic Transfer in Mammals via Soil and Water***

EPA assessed chronic non-cancer exposures to terrestrial mammals via trophic transfer from the water and soil to mammals using terrestrial mammal toxicity reference values derived from laboratory studies. More information on these data can be found in the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y).

For fish-eating mammals via the water pathway, both measured and modeled concentrations of HHCB in fish tissues, resulted in an RQ value below the benchmark of 1, preliminarily determining there is no unreasonable risk. For both measured and modeled concentrations of HHCB in fish tissues, the RQ values assume the mammals diet consists 100% of fish with a measurable concentration of HHCB. An additional refinement using a bioaccumulation model resulted in down-the-drain high-end scenarios with all calculated RQ values less than 1, further supporting EPA's preliminary determination that there is no unreasonable risk for fish-eating mammals.

For earthworm-eating mammals via the soil pathway, earthworms may be exposed to HHCB and there are known bioaccumulative properties of HHCB in earthworm tissues. Given this information, EPA calculated HHCB concentrations in earthworms from modeled soil HHCB concentrations. More information can be found in the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s). The maximum calculated RQ values were below the benchmark of 1, preliminarily determining there is no unreasonable risk. More information can be found in Section 2.4.3.

EPA has robust confidence in the protective nature of the risk estimates to terrestrial invertebrates and plants through comparisons with measured concentrations in soil and estimates of soil concentrations from biosolid applications to land. EPA also has robust confidence that the estimated concentrations of HHCB in fish represent an upper bound for the screening assessment. However, the Agency has less confidence that these upper-bound estimates represent HHCB concentrations in real fish tissue due to compounding conservative assumptions such as low flow rates, consistent releases, and predictable animal behaviors that are all unrealistic to assume over extended periods of time that would lead to chronic exposures. EPA has lower confidence in the estimated high-end HHCB concentrations in fish tissues because of no reasonably available evidence of fish in the United States having comparable concentrations. More information can be found in Section 2.4.2.

## 4.2 Unreasonable Risk to Human Health

Calculated non-cancer risk estimates (margin of exposure [MOEs] [5]) can provide a risk profile of HHCB by presenting a range of estimates for different health effects for different COUs. When characterizing the risk to human health from occupational exposures during risk evaluation, EPA conducts baseline assessments of risk and makes its determination of unreasonable risk in a manner that takes in consideration reasonably available information (*e.g.,* information submitted by manufacturers and processors of HHCB; representative site visits if relevant) regarding whether the use of respiratory protection or other PPE is standard practice at all sites. This allows EPA to make unreasonable risk determinations based on the reasonably available information regarding workers where the Agency has confidence that the information is representative of worker activities.

In this draft risk evaluation, because all of the MOEs calculated did not indicate risk, EPA did not consider PPE usage as part of the unreasonable risk determination. Calculations, including consideration of alternative bodyweights and PPE impacts, are provided in the *Draft Occupational Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ab) and in Section 3.4. EPA calculated non-cancer estimates for occupational, consumer, and general population exposures for intermediate and chronic exposures. Risks were not estimated for acute exposures for occupational and consumers because non-cancer health effects are unlikely to result from a single exposure at concentrations identified as described in Section 3.2 and in the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y). EPA did not calculate cancer risk estimates for HHCB as described in the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y).

To characterize risk from non-cancer endpoints, the estimated MOEs are compared to their respective benchmark MOE. The benchmark MOE of 30 accounts for the total uncertainty in a POD for HHCB. This POD is based on decreased offspring body weight and was used to characterize risk from exposure to HHCB for intermediate and chronic non-cancer exposures. An MOE that is less than the benchmark MOE is a starting point for informing a determination of unreasonable risk of injury to health, based on non-cancer effects. EPA also considered conservative assumptions to assess exposures in this preliminary unreasonable risk determination. It is important to emphasize that these calculated risk estimates and benchmarks alone are not bright-line indicators of unreasonable risk, and EPA has discretion to consider other risk-related factors in addition to risks identified in the risk characterization.

### 4.2.1 Populations and Exposures EPA Assessed for Human Health

EPA evaluated risk to workers, including female workers of childbearing age between 16 and 21 years, consumer users, and the general population using reasonably available monitoring and modeling data for intermediate and chronic non-cancer inhalation and ingestion exposures, as applicable. The Agency did not assess ONUs separately, but their exposures are expected to be similar or lower exposures than workers. EPA has evaluated the following populations and exposures to the following groups:

- Workers, including female workers of childbearing age between 16 and 21, from intermediate and chronic non-cancer inhalation exposures;
- Consumers from chronic non-cancer inhalation exposures; and
- General population from chronic non-cancer ingestion exposures via drinking water and fish ingestion (including subsistence fishers and tribal populations).

[5] EPA derives non-cancer MOEs by dividing the non-cancer POD (HEC [mg/m$^3$] or HED [mg/kg-day]) by the exposure estimate (mg/m$^3$ or mg/kg-day). Section 3.1.1 has additional information on the risk assessment approach for human health.

EPA did not evaluate risk for dermal exposures because HHCB is not hazardous through contact with skin. The weight of evidence supporting no dermal hazards is discussed in Section 2.3.2 of the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y).

For infant exposure from human milk, EPA could not derive meaningful risk estimates due to the absence of an infant-specific hazard value. Specifically, though the hazard value used to characterize risks (based on decreased offspring bodyweight) was relevant to nursing infants, the doses that provide the basis for the hazard value are maternal doses of HHCB rather than doses that were lactationally transferred to the offspring. However, EPA has confidence that the risk estimates calculated based on adult (maternal) exposures to HHCB in this assessment are also protective of a nursing infant's greater susceptibility during this unique lifestage, whether due to sensitivity or greater exposure per body weight. Further discussion of the human milk pathway is provided in Section 3.4.4.3.

Descriptions of the data used for human health exposure and human health hazards are provided in Sections 3.1 and 3.3. Uncertainties for overall exposures and hazards are presented in Section 3.1 and 3.2, respectively, and are considered in the unreasonable risk determination.

### 4.2.2 Summary of Human Health Effects

EPA has preliminarily determined that HHCB does not present unreasonable risk to human health from intermediate and chronic non-cancer inhalation exposures for workers, including female workers of childbearing age between 16 and 21 years, consumers, as well as intermediate and chronic non-cancer ingestion exposure for the general population.

With respect to the health endpoint upon which EPA has based this draft unreasonable risk determination, the Agency has robust overall confidence in the non-cancer POD, which is based on decreased offspring bodyweight, the dose-response, and the consistency across studies in relation to body weight. The confidence in the POD and descriptions of the data used to determine the human health effects from HHCB are explained in Section 3.1 and Section 2.4.4 of the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y). Both sections also provide more information about EPA's confidence in the health hazard of HHCB.

### 4.2.3 Basis for Unreasonable Risk to Human Health

In developing the exposure and hazard assessments for HHCB, EPA has analyzed reasonably available information to ascertain whether some human populations may have greater exposure and/or susceptibility than the general population to the hazard posed by HHCB. In this regard, the Agency identified PESS; people who are expected to have greater exposure to HHCB, including: women of reproductive age; pregnant women; infants, children and adolescents; people who frequently use consumer products and/or articles containing high-concentrations of HHCB; people exposed to HHCB in the workplace; people who may be in proximity to releasing facilities, including fenceline communities; and people whose diets include large amounts of fish, including subsistence fishers and tribal populations. These subpopulations are PESS because some have greater exposure to HHCB per body weight (*e.g.,* infants, children, adolescents) while some experience aggregate or sentinel exposures.

EPA evaluated all reasonably available information for occupational, consumer, and general population exposure to HHCB, including consideration of the potential for increased susceptibility across PESS considerations. Individuals can be exposed by inhaling HHCB as a vapor, mist, or dust or consuming water, human milk, fish, or soil contaminated with HHCB. For this draft risk evaluation, EPA relied on an approach of estimating COUs expected to have the highest exposure estimates for each population group and focused on generating the most conservative, upper-bound exposure routes as a screening to identify risk. Because risk was not indicated even with the use of conservative assumptions, refinements were not needed, and the Agency did not separately estimate ONUs or bystanders as these exposures would be similar or lower than the individuals directly exposed. Because HHCB is not acutely hazardous, EPA only considered intermediate and chronic non-cancer exposures.

EPA did conduct an aggregate analysis driven by drinking water and fish ingestion (oral) exposures for the general population, including subsistence fishers and tribal populations, along with inhalation exposures for workers, and consumers. More information on the aggregate analysis can be found in Section 3.4.6.

#### 4.2.3.1 Workers

Based on the occupational risk estimates and related risk factors, EPA has preliminarily determined that HHCB does not present unreasonable risk to workers, including female workers of childbearing age between 16 and 21 years, via the intermediate and chronic non-cancer inhalation route of exposure. ONUs were not evaluated for inhalation exposures because it is assumed that these exposure routes would be lower than workers who may be directly exposed to HHCB.

EPA relied on an approach of estimating COUs expected to have the highest exposure estimates for each population and focused on generating the most conservative, upper-bound exposure estimates as a screening analysis to identify risk. Of the 15 occupational COUs, two COUs were expected to have the highest exposure potential for vapor and dust inhalation and were therefore evaluated using the occupational exposure scenarios formulation of fragrance oils and plastic compounding/ converting. A crosswalk between each occupational COU and the associated exposure scenario can be found in Table 3-9. The remaining 13 occupational COUs were not quantitatively assessed because exposures were expected to be lower than those scenarios evaluated as part of the screening approach and are further explained below.

The two occupational COUs expected to have the highest inhalation exposure potential to HHCB are

- Processing – Incorporation into formulation, mixture or reaction product – In odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials; and
- Processing – Incorporation into articles – Odor agent in plastics material and resin manufacturing.

Both COUs were assessed via the intermediate and chronic non-cancer inhalation route and both exceeded the MOE of 30. Therefore, EPA has preliminarily determined that these two COUs do not present unreasonable risk for inhalation exposures. These COUs and associated exposure scenarios were determined to be the most conservative because of the high inhalation exposures. As such, EPA used these COUs as part of a screening approach and determined that because there was no associated risk for these COUs, similar occupational COUs that have lower concentrations, lower durations of exposure, and lower inhalation exposure potential, would also not likely contribute to the unreasonable risk. More information on the use of this screening approach can be found in Section 3.4.2.

As part of the screening analysis, the remaining 13 pccupational COUs were not quantitatively assessed because these COUs were determined to have lower exposures than the COUs assessed, uncertainties existed in the concentration of HHCB, or the inhalation route of exposure (vapor, dust, or mist) was not expected. EPA is confident that the COUs not quantitatively assessed result in lower exposures than COUs quantitatively assessed because of known lower concentrations, lower durations of exposure, or lower exposure potential. A detailed explanation for each COU and the inhalation exposure potential can be found in Appendix E of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). Based on the screening analysis and the preliminary determination of no unreasonable risk for the COUs with higher potential for exposure, EPA is also preliminarily determining that the following COUs do not contribute to the unreasonable risk presented by HHCB to human health for workers:

- Domestic manufacturing
- Manufacturing – Import
- Processing – Repackaging in odor agent in all other chemical product and preparation manufacturing
- Processing – Recycling
- Distribution in commerce
- Commercial use – Air fresheners for motor vehicles
- Commercial use – Continuous action air fresheners
- Commercial use – Instant action air fresheners
- Commercial use – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)
- Commercial use – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash)
- Commercial use – Plastic and rubber articles
- Commercial use – Laboratory chemicals
- Disposal.

EPA has moderate-to-robust confidence in the scientific evidence that demonstrates estimated inhalation exposures for HHCB can serve as upper-bound estimates of exposure in occupational settings. However, there is moderate confidence in the scientific evidence that demonstrates estimated inhalation exposures for HHCB vapor can serve as precise estimate of the real exposure to HHCB experienced by workers. This is further summarized in Section 3.3.1.2. More information on the occupational analysis can be found in Section 3.4.2 of the risk evaluation.

#### 4.2.3.2 Consumers

Based on the consumer risk estimates and related risk factors, EPA has preliminarily determined that HHCB does not present unreasonable risk to consumers via the chronic non-cancer inhalation route of exposure.

EPA relied on an approach of estimating COUs expected to have the highest exposure estimates for each population and focused on generating the most conservative, upper-bound exposure routes as a screening analysis to identify risk. Of the seven consumer COUs, one COU was expected to have the highest exposure potential for vapor inhalation and was therefore evaluated using the consumer exposure scenario, continuous action air freshener. The remaining six consumer COUs were not quantitatively assessed because exposures were expected to be lower than those scenarios evaluated as part of the screening approach and are further explained below.

The consumer use in continuous action air fresheners COU was assessed via the chronic non-cancer vapor inhalation route for adults and youth and risk estimates were all above the MOE of 30. Therefore, EPA has preliminarily determined that this COU does not present unreasonable risk for inhalation exposures. This COU and associated exposure scenario was determined to be the most conservative because HHCB concentrations in continuous action air fresheners are expected to be the highest and the duration of exposure is expected to be the longest in these types of products. As such, EPA used this COU as part of a screening approach and determined that because there was no associated risk for this COU, similar consumer COUs, which have lower concentrations and lower durations of exposure, would also not likely contribute to the unreasonable risk. More information on this screening approach can be found in Section 3.4.1.

Additionally, as part of the screening analysis, the remaining six consumer COUs were not quantitatively assessed because either these COUs were determined to be less conservative than the COUs assessed; there were some uncertainties in the concentration of HHCB; or the inhalation route of exposure, through vapor, dust, or mist, was not expected. EPA is confident that the COUs not quantitatively assessed result in lower exposures than COUs quantitatively assessed because of known lower concentrations and known lower durations of exposure. A detailed explanation for each COU can be found in Appendix E of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). Based on the screening analysis and the preliminary determination of no unreasonable risk for the COU with higher potential for exposure, EPA is also preliminarily determining that the following COUs do not contribute to the unreasonable risk presented by HHCB to human health:

- Consumer use – Air fresheners for motor vehicles
- Consumer use – Instant action air fresheners
- Consumer use – All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain)
- Consumer use – Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; Stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/granule); Dishwashing detergent liquid (hand-wash)
- Consumer Use – Plastic and rubber articles
- Consumer Use – Ion exchangers; Liquid water treatment products; Solid powder water treatment products.

EPA has moderate-to-robust confidence that the estimated inhalation exposures for HHCB represent high-end consumer and commercial exposure levels. However, EPA has slight confidence in the precision of these estimates as reflections of actual exposures due to the conservative assumptions used in the input modeling parameters and is summarized in Section 3.3.2.3. More information on the consumer analysis can be found in Section 3.3.2 of this draft risk evaluation.

#### 4.2.3.3 General Population

Based on the risk estimates for the general population and other related risk factors, EPA has preliminarily determined that for all down-the-drain and surface water scenarios evaluated, HHCB does not contribute to the unreasonable risk from the following exposure routes and pathways:

- chronic non-cancer ingestion exposure from drinking water; and
- chronic non-cancer ingestion exposure from fish consumption.

EPA was not able to develop COU-derived risk estimates due to the lack of COU-specific monitoring data for HHCB that would inform individual exposure scenarios. EPA did develop down-the-drain and surface water scenarios to better understand potential exposures related to ingestion from drinking water and fish consumption based on modeling and certain measured concentrations. These scenarios could include TSCA-derived HHCB COUs as well as other non-TSCA HHCB sources, such as those articles and products from personal care products not regulated under TSCA. More information on the methods used to develop these scenarios can be found in Section 3.3.3, Section 2.3 of the Draft HHCB Human

Exposure Assessment (U.S. EPA, 2026x), and Section 2.3 of *Draft HHCB* Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y).

EPA did not evaluate general population inhalation exposures of HHCB because the Agency determined these routes are unlikely due to the physical-chemical properties of HHCB in the ambient air, including deposition to soil. Furthermore, EPA did not evaluate general population exposures through incidental oral (ingestion) or incidental dermal exposures in surface water, as the Agency expects this route to be lower than long-term drinking water exposures, which were assessed. More information can be found in Section 2.3 of the Draft HHCB Human Health and Environmental Hazard Assessment (U.S. EPA, 2026y).

EPA did consider general population ingestion exposures from human milk but concluded during the analyses that the risk estimates based on adult exposure are considered to be protective; therefore, there are no significant contributions due to infant ingestion of human milk. More information can be found in Section 3.3.4.

Additionally, EPA also considered general population ingestion exposures from shellfish. The Agency conducted a high-level screening approach using high-end shellfish concentrations as a potential high-end general population exposure concentration. EPA determined that the high-end exposure concentrations for shellfish were less than the lowest fish tissue HHCB concentration due to lower ingestion rates in the general population. Because ingestion rates of shellfish across tribal and general populations are generally near or notably less than fish ingestion rates, EPA concluded that shellfish ingestion does not significantly contribute to unreasonable risk of HHCB to the general population. More information about these shellfish concentrations and ingestion rates can be found in Sections 3.4.4.

***Drinking Water***

Based on the risk estimates for the general population, including infants and youths, EPA has preliminarily determined that drinking water does not contribute to the unreasonable risk from chronic non-cancer ingestion exposures.

For chronic non-cancer exposures, all risk estimates calculated were above the MOE of 30—even without accounting for any HHCB removal during water treatment. For infants under 1 year of age, the most sensitive group assessed, the lowest MOE was an order of magnitude higher than the benchmark of 30. Based on these risk estimates for high-end exposures, EPA has preliminarily determined that drinking water does not contribute to the unreasonable risk of chronic non-cancer exposures to HHCB.

***Fish Ingestion***

Based on the risk estimates for the general population, including subsistence fishers,[6] tribal fishers,[7] and other related risk factors, EPA has preliminarily determined that fish ingestion does not contribute to unreasonable risk from chronic, non-cancer ingestion exposures. The Agency first conducted high-level screening exposure scenarios using high-end surface water concentrations and high-end fish tissue concentrations for chronic exposures. EPA then relied on a more refined analysis using a bioaccumulation derived model for chronic exposures. In summary, the Agency has preliminarily determined that fish ingestion does not contribute to unreasonable risk of chronic non-cancer exposures to HHCB.

[6] Subsistence fishers represent a PESS group for HHCB due to their increased exposure via fish ingestion (142.4 g/day compared to a high-end of 22.2 g/day for the general population).
[7] Tribal fishers represent a PESS group for HHCB due to their increase exposure via fish ingestion (216 g/day) (see Section 3.2.6).

For chronic non-cancer exposures, fish tissues were calculated from modeled fish tissue concentrations derived from surface water concentrations. For both models used, the high-end screening exposure model and the more refined bioaccumulation derived model, all risk estimates calculated exceeded the MOE of 30. Both models rely on a series of conservative assumptions including constant surface water concentrations of HHCB and the number of fish remaining within the water column in which the constant HHCB concentration is found. These models do not account for individual actions or a species natural behavior. These assumptions also do not consider changes in HHCB concentrations that may occur on a daily basis through weather patterns or discharge points where such concentrations downstream would be expected to decrease as a result of dilution and flow rates. The bioaccumulation-derived model provides whole fish tissue concentrations—even when considering a constant exposure to surface water with high HHCB concentrations. This refinement considers dose and dietary exposures specifically to mammals that consume aquatic organisms.

Based on the high-level screening model analysis as well as the bioaccumulation-derived model analysis, EPA has preliminarily determined that fish ingestion by the general population, including subsistence fishers and tribal fishers, does not contribute to the unreasonable risk for chronic non-cancer exposures to HHCB. More information on the concentrations within fish tissues can be found in the *Draft Fish Ingestion Risk Calculator for for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026v) for all exposure estimates. More information on the bioaccumulation dervied model analysis can be found in Appendix F of the Draft HHCB Environmental Exposure Assessment (U.S. EPA, 2026s).

EPA's overall confidence is moderate-to-robust in the scientific evidence that demonstrates estimated ingestion exposures for HHCB can serve as high-end estimates for general population exposure to HHCB as well as the precision of the high-end fish tissue concentrations. This information is summarized in Section 3.4.4.1. More information on the general population analysis can be found in Sections 3.3.3 and 3.4.4 of this draft risk evaluation.

#### 4.2.3.4 Aggregate Analysis

Based on the aggregate risk estimates and related risk factors, EPA has preliminarily determined that HHCB does not present unreasonable risk through an aggregate analysis for workers, consumers, and the general population via the chronic, non-cancer inhalation and ingestion routes of exposure.

EPA assessed aggregate risks from long-term exposure to HHCB, considering inhalation and ingestion exposure among consumers, workers, and the general population as detailed in the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). Three long-term aggregate scenarios were estimated by combining routinely expected exposure pathways as follows:

- **Aggregate Exposure Scenario 1 (Worker + Drinking Water + Fish Ingestion [Adult, >21 Years]):** Workplace inhalation (HHCB dust during compounding/converting) combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 3.4.6).
- **Aggregate Exposure Scenario 2 (Consumer + Drinking Water + Fish Ingestion [Adult, >21 Years]):** Consumer inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water and fish (combined down-the-drain release scenario for subsistence fisher exposure; see Section 3.4.6).
- **Aggregate Exposure Scenario 3 (Consumer [Infant, <1 Year] + Drinking Water):** Consumer (infant) inhalation from continuous action air fresheners at home combined with oral ingestion from HHCB in drinking water.

The chronic non-cancer risk estimates for these three scenarios were all above the MOE of 30. Therefore, EPA has preliminarily determined that HHCB derived COUs do not present unreasonable risk as part of an aggregate analysis for inhalation and ingestion exposures. These estimates were based on high-end exposure concentrations and assumptions. More information can be found in Sections 3.4.6.

## 4.3 Additional Information Regarding the Basis for the Unreasonable Risk Determination

Table 4-1 summarizes the basis for this draft unreasonable risk determination of injury to the environment presented in this draft HHCB risk evaluation. It also identifies the duration of exposure and the exposure route to environmental receptors. Table 4-2 and Table 4-3 summarize the basis for this draft unreasonable risk determination of injury to human health presented for occupational and consumer COUs, respectively. Both tables identify the duration of exposure (*e.g.,* intermediate or chronic duration) and the exposure route to the population. As explained in Section 4.2, for this preliminary unreasonable risk determination, EPA has considered the effects of HHCB to human health, including PESS, a range of risk estimates as appropriate, risk-related factors, and the confidence in the analysis. See Section 3.4 for a summary of risk estimates.

**Table 4-1. Supporting Basis for the Unreasonable Risk Determination for the Environment**

| Life Cycle Stage | Category | Subcategory | Exposure Scenario | Population/ Receptor | Compartment [a] | Environmental Concentration Level [b] | Environmental Effects | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Acute | Chronic |
| Manufacturing | Domestic manufacturing | Domestic manufacturing | Industrial Release – Manufacturing (TRI Data) | Aquatic | Surface water | Central Tendency | 0.08 | 0.36 |
| | | | | | | High-End | 0.13 | 0.06 |
| | | | | | Sediment | Central Tendency | N/A | 0.07 |
| | | | | | | High-End | N/A | 0.45 |
| | Import | Import | Industrial Release – Processing; Repackaging (TRI Data) | Aquatic | Surface water | Central Tendency | 0.02 | 0.08 |
| | | | | | | High-End | 0.00 | 0.01 |
| | | | | | Sediment | Central Tendency | N/A | 0.10 |
| | | | | | | High-End | N/A | 0.02 |
| Processing | Incorporation into formulation, mixture or reaction product | Odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, Cleaning compound, and toilet preparation manufacturing; fragrance mixtures and fragrance raw materials | Industrial Release – Processing; Formulation of Fragrance Oils (TRI Data) | Aquatic | Surface water | Central Tendency | 0.00 | 0.16 |
| | | | | | | High-End | 0.04 | 0.03 |
| | | | | | Sediment | Central Tendency | N/A | 0.20 |
| | | | | | | High-End | N/A | 0.03 |
| | Incorporation into articles | Odor agent in plastics material and resin manufacturing | Industrial Release – Processing; Formulation of End-Use Products (TRI Data) | Aquatic | Surface water | Central Tendency | 0.02 | 0.08 |
| | | | | | | High-End | 0.00 | 0.01 |
| | | | | | Sediment | Central Tendency | N/A | 0.10 |
| | | | | | | High-End | N/A | 0.02 |
| | Repackaging | Odor agent in all other chemical product and preparation manufacturing | Industrial Release – Processing; Repackaging (TRI Data) | Aquatic | Surface water | Central Tendency | 0.00 | 0.02 |
| | | | | | | High-End | 0.00 | 0.00 |
| | | | | | Sediment | Central Tendency | N/A | 0.02 |
| | | | | | | High-End | N/A | 0.00 |
| Distribution in commerce | Distribution in commerce | Distribution in commerce | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| Commercial use | Air care products | Air fresheners for motor vehicles | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Air care products | Continuous action air fresheners | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Air care products | Instant action air fresheners | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |

| Life Cycle Stage | Category | Subcategory | Exposure Scenario | Population/ Receptor | Compartment [a] | Environmental Concentration Level [b] | Environmental Effects | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Acute | Chronic |
| Commercial use | Cleaning and furnishing care products | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) | Down-the-drain; Commercial | Aquatic | Surface water | CT | 0.01 | 0.03 |
| | | | | | | High-End | 0.16 | 0.68 |
| | | | | | Sediment | CT | N/A | 0.04 |
| | | | | | | High-End | N/A | 0.84 |
| | Plastic and rubber articles not covered elsewhere | Plastic and rubber articles | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Other use laboratory chemicals | Laboratory chemicals | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| Consumer use | Air care products | Air fresheners for motor vehicles | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Air care products | Continuous action air fresheners | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Air care products | Instant action air fresheners | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Plastic and rubber products not covered elsewhere | Plastic and rubber articles | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |
| | Cleaning and furnishing care products | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) | Down-the-drain; Consumer[c] | Aquatic | Surface water | CT | 0.02 | 0.08 |
| | | | | | | High-End | 0.44 | 1.92 |
| | Chemical substances in treatment products | Ion exchangers; Liquid water treatment products; Solid powder water treatment products | | | Sediment | CT | N/A | 0.10 |
| | | | | | | High-End | N/A | 2.34 |
| Disposal | Disposal | Disposal | Releases to the environment not expected; see Section 1.4.1 for more information. | | | | | |

| Life Cycle Stage | Category | Subcategory | Exposure Scenario | Population/ Receptor | Compartment [a] | Environmental Concentration Level [b] | Environmental Effects | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Acute | Chronic |

[a] For terrestrial organisms via the land pathway, the maximum reported HHCB concentration in biosolids was used as a screening assessment because of a lack of available data related to specific TSCA COUs described in this assessment. Therefore, no COU derived exposure scenario and RQ exist for soil and land. More information can be found in Section 4.3.4.

[b] The P95 publicly owned treatment works (POTW) scenario represents a combination of POTW population data and receiving water body flow, such that the concentration in the receiving water body is expected to be higher than 95% of the POTWs in the country. This could be considered a high-end scenario. Likewise, the P50 POTW represents the concentration in the receiving water body that is expected to be higher than 50% of the POTWs in the country. This could be considered a central tendency scenario. More information on the development of these scenarios can be found in Sections 1.4.1 and 2.3.

[c] Although the risk estimates indicate risk for high-end exposures for the *down-the-drain; consumer* release scenario, EPA is preliminarily determining that these COUs do not contribute to the unreasonable risk to the environment and are therefore not bolded in this table. See Section 4.1 for more information.

**Table 4-2. Supporting Basis for the Unreasonable Risk Determination for Human Health (Occupational COUs)**

| Life Cycle Stage | Category | Subcategory[a] | Exposure Scenario | Population | Exposure Route | Exposure Level | Human Health Effects | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Intermediate Non-Cancer | Chronic Non-Cancer |
| | | | | | | | Inhalation MOE =30 | Inhalation MOE =30 |
| Processing | Incorporation into formulation, mixture or reaction product | Odor agent in all other chemical product and preparation manufacturing; Miscellaneous manufacturing; Soap, cleaning compound, and toilet preparation manufacturing; Fragrance mixtures and fragrance raw materials | Formulation of fragrance oils | Workers, Adults | Inhalation | Central Tendency | 38,101 | 40,794 |
| | | | | | | High-End | 4,198 | 4,495 |
| | | | | Workers, Women of Childbearing Age (16 to <21) | Inhalation | Central Tendency | 31,386 | 33,604 |
| | | | | | | High-End | 3,458 | 3,703 |
| | Incorporation into articles | Odor agent in plastics material and resin manufacturing | Plastic compounding/ converting | Workers, Adults | Inhalation | Central Tendency | 430 | 460 |
| | | | | | | High-End | 103 | 110 |
| | | | | Workers, Women of Childbearing Age (16 to <21) | Inhalation | Central Tendency | 354 | 379 |
| | | | | | | High-End | 85 | 91 |

MOE = margin of exposure

[a] Only select occupational COUs, as part of the screening analysis of the high-end "bounding" COUs, have risk estimates and are presented in Table 6-2. Risk estimates for the remaining occupational COUs were not calculated as further explained in Section 3.3.1 and Appendix E of the Draft HHCB Human Exposure Assessment (U.S. EPA, 2026x). For general population exposures, EPA was not able to develop COU-derived risk estimates due to the lack of COU-specific monitoring data for HHCB that would inform individual exposure scenarios. The Agency developed down-the-drain and surface water scenarios to better understand potential exposures related to ingestion from drinking water and fish consumption based on modeling and certain measured concentrations. The exact risk estimates based on these scenarios can be found in Section 3.4.2 and an explanation on the potential unreasonable risk can be found in Section 4.2.3.3.

**Table 4-3. Supporting Basis for the Unreasonable Risk Determination for Human Health (Consumer COUs)**

| Life Cycle Stage | Category | Subcategory[a] | Exposure Scenario | Exposure Route | Exposure Level | Population | Human Health Effects |
|---|---|---|---|---|---|---|---|
| | | | | | | | Chronic Non-Cancer Inhalation MOE = 30 |
| Consumer Use | Air care products | Continuous action air fresheners | Continuous action air fresheners | Inhalation | High-End | Adult (≥21 years) | 35,600 |
| | | | | | | Youth (16–20 years) | 30,200 |
| | | | | | | Youth (11–15 years) | 24,000 |
| | | | | | | Child (6–10 years) | 15,897 |
| | | | | | | Child (3–5 years) | 9,304 |
| | | | | | | Infant (1–2 years) | 5,764 |
| | | | | | | Infant (<1 year) | 5,583 |

[a] Only select consumer COUs, as part of the screening analysis of the high-end "bounding" COUs, have risk estimates and are presented in this table. Risk estimates for the remaining consumer COUs were not calculated as further explained in Section 3.3.2. and Appendix E of the Draft HCCB Human Exposure Assessment (U.S. EPA, 2026x).

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U.S. EPA. (2026e). Draft Consumer Chronic Inhalation Risk Calculator 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.

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U.S. EPA. (2026h). 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. (2026i). 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. (2026j). Draft Data Extraction 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. (2026k). 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. (2026l). Draft Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport 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 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. (2026n). 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. (2026o). 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. (2026p). 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. (2026q). 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. (2026r). 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. (2026s). 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. (2026t). Draft Environmental Release Modeling 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. (2026u). Draft Ethics Reviews for Intentional Human Dosing Studies 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. (2026v). Draft Fish Ingestion Risk Calculator 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. (2026w). Draft General Population Surface Water Risk Calculator 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. (2026x). 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. (2026y). 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. (2026z). Draft KABAM Modeling 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. (2026aa). Draft Occupational Exposure Modeling 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. (2026ab). Draft Occupational Risk Calculator 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. (2026ac). Draft POTW Release Scenario Development 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. (2026ad). Draft SHEDS-HT Consumer Product Modeling Files 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. (2026ae). Draft Summary of Toxics Release Inventory (TRI) Water Releases 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. (2026af). Draft Systematic Review Protocol 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. (2026ag). Draft Water Quality Portal Results 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.

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# APPENDICES

## Appendix A KEY ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 7Q10 | Lowest 10-day average flow that occurs (on average) once every 10 years |
| 30Q5 | Lowest 30-day average flow that occurs (on average) once every 5 years |
| ACGIH | American Conference of Governmental Industrial Hygienists |
| ADD | Average daily dose |
| ADR | Acute dose rate |
| BAF | Bioaccumulation factor |
| BASE | Buildings Assessment Survey and Evaluation Study (EPA) |
| BCF | Bioconcentration factor |
| BMD | Benchmark dose |
| CASRN | Chemical Abstracts Service Registry Number |
| CBI | Confidential business information |
| CDR | Chemical Data Reporting |
| CEM | Consumer Exposure Model |
| CFR | Code of Federal Regulations |
| COC | Concentration of concern |
| COU | Condition of use |
| CSCL | Chemical Substances Control Law |
| DMR | Discharge Monitoring Report |
| DER | Data Evaluation Record (EPA/OPP) |
| DTD | Down-the-drain |
| ECHA | European Chemicals Agency |
| EOGRT | Extended one-generation reproductive toxicity |
| EPA | Environmental Protection Agency (U.S.) |
| ESD | Emission scenario document |
| ECEL | Existing Chemical Exposure Limit |
| FCA | Fragrance Creators Association |
| GS | Generic scenario |
| HEC | Human equivalent concentration |
| HED | Human equivalent dose |
| HHCB | 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran |
| KABAM | $K_{OW}$ (based) Aquatic BioAccumulation Model |
| $K_{OA}$ | Octanol/air partition coefficient |
| $K_{OC}$ | Organic carbon/water partition coefficient |
| $K_{OW}$ | Octanol/water partition coefficient |
| LCD | Life cycle diagram |
| MOA | Mode of action |
| MOE | Margin of exposure |
| NAICS | North American Industry Classification System |
| NEI | National Emissions Inventory |
| NIOSH | National Institute for Occupational Safety and Health (U.S.) |
| OECD | Organisation for Economic Co-operation and Development |
| OES | Occupational exposure scenario |
| ONU | Occupational non-user |
| OPP | Office of Pesticide Program (EPA) |
| OPPT | Office of Pollution Prevention and Toxics (EPA) |

| | |
|---|---|
| OSHA | Occupational Safety and Health Administration (U.S.) |
| PEL | Permissible exposure limit |
| PESS | Potentially exposed or susceptible subpopulations |
| POD | Point of departure |
| POTW | Publicly owned treatment works |
| PPE | Personal protective equipment |
| PSC | Point Source Calculator |
| PV | Production volume |
| ReCAAP | Rethinking Chronic Toxicity and Carcinogenicity Assessment for Agrochemicals Project |
| RQ | Risk quotient |
| RS | Release Scenario |
| SACC | Science Advisory Committee on Chemicals |
| SDS | Safety data sheet |
| STEV | Short-term occupational exposure value |
| TLV | Threshold limit value |
| TRI | Toxics Release Inventory |
| TRV | Toxicity reference value |
| TSCA | Toxic Substances Control Act |
| TSD | Technical support document |
| TWA | Time-weighted average |
| UF | Uncertainty factor |
| U.S. | United States |
| VVWM | Variable Volume Water Model |
| WWTP | Wastewater treatment plant |

# Appendix B REGULATORY AND ASSESSMENT HISTORY

The chemical substance, HHCB, is subject to federal and state laws and regulations in the United States (Table_Apx B-1 and Table_Apx B-2). Regulatory actions by other governments, tribes, and international agreements applicable to HHCB are listed in Table_Apx B-3. EPA conducted a search of existing domestic and international laws, regulations, and assessments pertaining to HHCB.

## B.1 Federal Laws and Regulations

**Table_Apx B-1. Federal Laws and Regulations**

| Statutes/Regulations | Description of Authority/Regulation | Description of Regulation |
|---|---|---|
| EPA regulations | | |
| Toxic Substances Control Act (TSCA) – section 6(b) | EPA is directed to identify high-priority chemical substances for risk evaluation; and conduct risk evaluations on at least 20 high priority substances no later than three and one-half years after the date of enactment of the Frank R. Lautenberg Chemical Safety for the 21st Century Act. | HHCB is one of the 20 chemicals EPA designated as a High-Priority Substance for risk evaluation under TSCA (84 FR 71924, December 30, 2019). Designation of formaldehyde as high-priority substance constitutes the initiation of the risk evaluation on the chemical. |
| Toxic Substances Control Act (TSCA) – section 8(a) | The TSCA section 8(a) CDR Rule requires manufacturers (including importers) to give EPA basic exposure-related information on the types, quantities and uses of chemical substances produced domestically and imported into the United States. | HHCB manufacturing (including importing), processing and use information is reported under the CDR rule (85 FR 20122, April 9, 2020). |
| Toxic Substances Control Act (TSCA) – section 8(b) | EPA must compile, keep current and publish a list (the TSCA Inventory) of each chemical substance manufactured (including imported) or processed in the United States. | HHCB was on the initial TSCA Inventory and therefore was not subject to EPA's new chemicals review process under TSCA Section 5 (60 FR 16309, March 29, 1995). |
| Toxic Substances Control Act (TSCA) – section 8(e) | Manufacturers (including importers), processors, and distributors must immediately notify EPA if they obtain information that supports the conclusion that a chemical substance or mixture presents a substantial risk of injury to health or the environment. | One risk report was received for HHCB (May 1997) (U.S. EPA, ChemView, Accessed March 22, 2019). |
| Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) – sections 3 and 6 | FIFRA governs the sale, distribution and use of pesticides. Section 3 of FIFRA generally requires that pesticide products be registered by EPA prior to distribution or sale. EPA assesses the whole formulation of pesticide products including active ingredients which have pesticidal effects and inert ingredients that do not. EPA keeps lists of inert ingredients that | HHCB is an approved nonfood use inert ingredient and as a component of a fragrance. (InertFinder, Accessed March 22, 2019). |

| Statutes/Regulations | Description of Authority/Regulation | Description of Regulation |
|---|---|---|
| | have been approved for use in pesticide products distinguishing between those that have been approved for use on food and those that have not. Pesticide products may only be registered if, among other things, they do not cause "unreasonable adverse effects on the environment." Section 6 of FIFRA provides EPA with the authority to cancel pesticide registrations if either (1) the pesticide, labeling, or other material does not comply with FIFRA; or (2) when used in accordance with widespread and commonly recognized practice, the pesticide generally causes unreasonable adverse effects on the environment. | |

## B.2 State Laws and Regulations

**Table_Apx B-2. State Laws and Regulations**

| State Actions | Description of Action |
|---|---|
| Chemicals of High Concern to Children | Minnesota includes HHCB in the list of chemicals of high concern (Toxic Free Kids Act Minn. Stat. 116.9401 to 116.9407). |
| Other | California lists HHCB as a designated priority chemical for biomonitoring (California SB 1379). The Oregon Department of Environmental Quality lists HHCB as a priority persistent pollutant (Oregon SB 737). |

## B.3 International Laws and Regulations

**Table_Apx B-3. International Laws and Regulations**

| Country/ Organization | Requirements and Restrictions |
|---|---|
| European Union | HHCB is registered for use in the EU (Chemicals Agency (ECHA) database, Accessed April 2, 2019). |
| Australia | HHCB was assessed under Human Health Tier II of the Inventory MultiTiered Assessment and Prioritisation (IMAP). Use reported include washing and cleaning products; air care products; anti-odour agents; floor and surface treatment products; scented clothes and papers; car care products; photochemicals; leather tanning and textile dyes; coatings and 95 Country/ Organization Requirements and Restrictions paint thinners; polishes and wax blends; and adsorbents. (NICNAS, 2019, Accessed April 4, 2019). |
| Japan | HHCB is regulated in Japan under the following legislation: • Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc. (Chemical Substances Control Law; CSCL) (NITE, 2019, Accessed April 4, 2019). |

# Appendix C LIST OF TECHNICAL SUPPORT DOCUMENTS AND SUPPLEMENTAL FILES

The list below provides all TSDs and supplemental files associated with this draft risk evaluation (document "01"). These include discipline-specific assessments, systematic review results, risk calculations, modeling outputs, and public communication documents.

**Systematic Review Protocol and Data Quality Evaluation and Data Extraction Documents –** Provide additional detail and information on systematic review methodologies used as well as the data quality evaluations and extractions criteria and results.

*2. Draft Systematic Review Protocol for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026af) – 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. This supplemental file may also be referred to as the "Draft HHCB Systematic Review Protocol."

*3. 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, 2026q) – Provides a compilation of tables for the data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of human health hazard animal toxicity information.

*4. 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, 2026k) – Provides a compilation of tables for the data extraction and data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation for dermal absorption.

*5. Draft Data Extraction 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, 2026j) – Provides a compilation of tables for the data extraction for HHCB. Each table shows the data point, set, or information element that was extracted from a data source that has information relevant for the evaluation of general population, consumer, and environmental exposure.

*6. 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, 2026o) – Provides a compilation of tables for the data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of environmental hazard toxicity information.

*7. 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, 2026p) – Provides a compilation of tables for the data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of general population, consumer, and environmental exposure.

*8. 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, 2026r) – Provides a compilation of tables for the data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of epidemiological information.

*9. 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, 2026n) – Provides a compilation of tables for the data extraction and data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation of physical and chemical properties.

*10. 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, 2026m) – Provides a compilation of tables for the data extraction and data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation of environmental release and occupational exposure.

*11. Draft Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026l) – Provides a compilation of tables for the data extraction and data quality evaluation information for HHCB. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation for environmental fate and transport.

*12. 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, 2026i) – Provides a compilation of tables for the data extraction for DBP. Each table shows the data point, set, or information element that was extracted from a data source that has information relevant for the evaluation of environmental hazard and human health hazard animal toxicology and epidemiology information.

**Technical Support Documents and Supplemental Files** – Provide additional details and information on physical chemistry, fate, exposure, hazard, and risk assessments.

*13. 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)* (U.S. EPA, 2026s)

*14. 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, 2026y)

*15. 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, 2026x)

*16. Draft Benchmark Dose Modeling Results for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026c)

*17. 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, 2026h)

*18. Draft Consumer Chronic Inhalation Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026e)

*19. Draft Occupational Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ab)

*20. Draft Aggregate Chronic Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026b)

*21. Draft Fish Ingestion Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026v)

*22. Draft Product Concentration Data Masterlist for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2025b)

*23. Draft Ethics Reviews for Intentional Human Dosing Studies for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026u)

*24. Draft General Population Surface Water Risk Calculator for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026w)

*25. Draft POTW Release Scenario Development for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ac)

*26. Draft Consumer Down the Drain POTW Release Calculations for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026f)

*27. Draft Commercial Down the Drain POTW Release Calculations for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026d)

*28. Draft SHEDS-HT Consumer Product Modeling Files for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026ad*)*

*29. Draft Environmental Release Modeling for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026t*)*

*30. Draft Occupational Exposure Modeling for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026aa*)*

*31. Draft Water Quality Portal Results for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026ag*)*

*32. Draft Consumer Exposure Modeling of Continuous Action Air Fresheners for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026g*)*

*33. Draft Summary of Toxics Release Inventory (TRI) Water Releases for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB)* (U.S. EPA, 2026ae)

*34. Draft KABAM Modeling for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026z*)*

*35. Draft ADME-B Modeling for 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[γ]-2-benzopyran (HHCB) (*U.S. EPA, 2026a*)*

# Appendix D CONDITIONS OF USE

This appendix provides detailed descriptions of the conditions of use (COUs) considered for the HHCB draft risk evaluation, pursuant to the TSCA section 3(4) definition of "conditions of use" and TSCA section 3(2) definition of "chemical substance." This appendix also presents an explanation of EPA's rationale for any changes to the scope of the risk evaluation after publication of the *Final Scope for the Risk Evaluation for HHCB; CASRN 1222-05-5* (U.S. EPA, 2020d).

## D.1 Conditions of Use Descriptions

The following descriptions are intended to include examples of uses so as not to exclude other activities that may also be included in the COUs of the chemical substance. To better describe the COU, EPA considered CDR submissions from the last two CDR cycles for HHCB (CASRN 1222-05-5) and the COU descriptions reflect what EPA identified as the best fit for that submission. Examples of articles, products, or activities are included in the following descriptions to help describe the COU but are not exhaustive. EPA uses the terms "articles" and "products" or "product mixtures" in the following descriptions and is generally referring to articles and products as defined by 40 CFR part 751. There may be instances where the terms are used interchangeably by a company or commenters, or by EPA, in reference to a code from the CDR reports (*e.g.,* "plastic products manufacturing," or "fabric, textile, and leather products.")

### D.1.1 Manufacturing – Domestic Manufacturing

Domestic manufacturing means to manufacture or produce HHCB within the Unites States. For purposes of the HHCB risk evaluation, this includes the extraction of HHCB from a previously existing chemical substance or complex combination of chemical substances and loading and repackaging (but not transport) associated with the manufacturing or production of HHCB.

HHCB is typically manufactured by a three-step reaction process (Wiley-VCH, 2002); (Zviely, 2002):

1. A cycloaddition reaction of alpha-methyl styrene and 2-methyl-2-butene (*i.e.,* amylene) is performed under acidic conditions to obtain 1,1,2,3,3-pentamethylindane (1).
2. The pentamethylindane (1) is hydroxyalkylated with propylene oxide in a Friedel-Crafts reaction using aluminum chloride as a catalyst.
3. The ring closure of the resulting 1,1,2,3,3-pentamethyl-5-(-hydroxyisopropyl)indane (2) to 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-γ-benzopyran (HHCB; Galaxolide) is accomplished with paraformaldehyde and a lower aliphatic alcohol via the acetal or with paraformaldehyde and a carboxylic acid anhydride via the acylate.

### D.1.2 Manufacturing – Importing

Import refers to the import of HHCB into the customs territory of the United States. This condition of use includes loading/unloading and repackaging (but not transport) associated with the import of HHCB. In general, chemicals may be imported into the United States in bulk via water, air, land, and intermodal shipments. These shipments take the form of oceangoing chemical tankers, railcars, tank trucks, and intermodal tank containers. Imported HHCB is shipped in liquid or other solid form, such as a gel. EPA anticipates that HHCB is shipped in bulk containers and may be repackaged into smaller containers for resale, such as drums or bottles. The type and size of container will vary depending on customer requirements.

As reported to EPA during the 2020 CDR reporting period and described here as a range to protect production volumes that were claimed as confidential business information (CBI), total production volume of HHCB in 2019 was between 1 million and less than 10 million lb (U.S. EPA, 2019a).

#### D.1.3 Processing – Incorporation into a Formulation, Mixture, or Reaction Product – Odor Agent in All Other Chemical Product and Preparation Manufacturing; Miscellaneous Manufacturing; Soap, Cleaning Compound, and Toilet Preparation Manufacturing; Fragrance Mixtures and Fragrance Raw Materials

This COU refers to the preparation of a product; that is, the incorporation of HHCB into formulation, mixture, or a reaction product which occurs when a chemical substance is added to a product (or product mixture), after its manufacture, for distribution in commerce—in this case, processing of HHCB as an odor agent in all other chemical product and preparation manufacturing; miscellaneous manufacturing; soap, cleaning compound, and toilet preparation manufacturing; and fragrance mixtures and fragrance raw materials (U.S. EPA, 2019a).

Imported HHCB is incorporated during plastics resin manufacturing. EPA also received a public comment that HHCB is incorporated into plastic pellets (EPA-HQ-OPPT-2018-0430-0017). The process involves mixing or blending HHCB into a formulation, mixture, or reaction product to obtain a product or mixture that is further used to make a finished product or article. These are then used in the manufacturing of products and articles described in other COUs including air care products, cleaning and furniture care products, and laundry and dishwashing products.

#### D.1.4 Processing – Incorporation into Articles – Odor Agent in Plastics Material and Resin Manufacturing

This COU refers to the preparation of an article; that is, the incorporation of HHCB into articles, meaning HHCB becomes a component of the article, after its manufacture, for distribution in commerce. In this case, HHCB is incorporated into an article as an odor agent in plastics material and resin manufacturing.

HHCB is incorporated into articles during article manufacturing, or from manufacturing of articles with plastic resins that contain HBCD (see *Processing – Incorporation into formulation, mixture, or reaction product* COU). EPA received public comment that HHCB is incorporated into plastic pellets (covered in the *Processing – Incorporation into formulation, mixture, or reaction product* COU) that are then used to produce scented articles (EPA-HQ-OPPT-2018-0430-0017).

#### D.1.5 Processing – Repackaging – Odor Agent in All Other Chemical Product and Preparation Manufacturing

Repackaging refers to the preparation of HHCB for distribution in commerce in a different form, state, or quantity than originally received or stored by various industrial sectors, including the repackaging of HHCB as an odor agent in all other chemical product and preparation manufacturing. This COU includes the transferring of HHCB from a bulk storage container into smaller containers. This COU would not apply to the relabeling or redistribution of a chemical substance without removing the chemical substance from the original container it was supplied in.

EPA has not identified specific information, besides CDR reporting, that describes the repackaging of HHCB.

#### D.1.6 Processing – Recycling

This COU refers to the process of treating generated waste streams (*i.e.,* which would otherwise be disposed of as waste), containing HHCB, that are collected, either on-site or at a third-party site, for commercial purposes.

EPA has not identified specific information for recycling of HHCB.

#### D.1.7 Distribution in Commerce

For purposes of assessment in this risk evaluation, distribution in commerce consists of the transportation associated with the moving of HHCB or HHCB-containing products and articles between sites manufacturing, processing or recycling HHCB or HHCB-containing products and articles, or to final use sites, or for final disposal of HHCB or HHCB-containing products and/or articles. More broadly under TSCA, "distribution in commerce" and "distribute in commerce" are defined under TSCA section 3(5).

#### D.1.8 Commercial Use – Air Care Products – Air Fresheners for Motor Vehicles

This COU is referring to the commercial use of HHCB as a chemical substance in air care products, specifically air fresheners for motor vehicles.

HHCB is used as a deodorizer in air fresheners for motor vehicles. Commercial uses of these items may include the use of air care products for odor reduction near professional drivers and deodorizing during car detailing. Other products can include hanging air fresheners on a commercial vehicle's rearview mirror or clipped on the vehicle's air vents which act as an instant action air freshener. These particular products differ from the COU *Air care products – Instant action air fresheners,* in that products under this COU are specifically designed and exclusively sold for use in vehicles.

EPA expects that some of these products, such as hanging air fresheners, are likely to be used in both commercial and consumer applications.

#### D.1.9 Commercial Use – Air Care Products – Continuous Action Air Fresheners

This COU is referring to the commercial use of HHCB as a chemical substance in air care products, specifically continuous action air fresheners. Continuous action products use a heat source to vaporize the fragrance and release the fragrance gradually and consistently over a longer period.

HHCB is used as a deodorizer in continuous action air fresheners in commercial settings, using metered sprayer systems. These large systems dispense aerosol products automatically on a continuous or periodic (timed) basis. Primary uses for such systems include hotels, restaurants, stadiums, museums, theaters and other commercial spaces. EPA expects that these larger systems are likely to be exclusively used in commercial settings. Other products include solid-room air fresheners, aroma chemicals, and scented candles. Public comments identified HHCB in candles, fragrance oils, scented bathroom clips, and air freshener plug-ins (U.S. EPA, 2019a); (EPA-HQ-OPPT-2018-0430-0012).

#### D.1.10 Commercial Use – Air Care Products – Instant Action Air Fresheners

This COU is referring to the commercial use of HHCB as a chemical substance in air care products, specifically instant action air fresheners. Instant action air fresheners are aerosols or atomizers that manually dispense when needed.

Instant action air fresheners include carpet and room deodorizers and pet odor spray.

EPA expects that some of these products are likely to be used in both commercial and consumer applications.

#### D.1.11 Commercial Use – Cleaning and Furnishing Care Products – All-Purpose Foam Spray Cleaner; All-Purpose Liquid Cleaner/Polish; All-Purpose Liquid Spray Cleaner; All-Purpose Waxes and Polishes; Appliance Cleaners; Drain and Toilet Cleaners (Liquid); Powder Cleaners (Floors); Powder Cleaners (Porcelain)

This COU is referring to the commercial use of HHCB as a chemical substance in cleaning and furnishing care products such as all-purpose foam spray cleaners, polishes, liquid spray cleaners, waxes and polishes, appliance cleaners, liquid drain and toilet cleaners, and powder cleaners for floors and porcelain surfaces.

HHCB is an ingredient in bathroom mold and mildew cleaner, carpet and room deodorizing products, multi-surface floor cleaning products, glass cleaning products, and hard surface cleaning products.

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.12 Commercial Use – Laundry and Dishwashing Products – Laundry Detergent (Liquid); Laundry Detergent (Unit Dose/Granule); Fabric Enhancers; Stain Removers; Dishwashing Detergent (Liquid/ Gel); Dishwashing Detergent (Unit Dose/ Granule); Dishwashing Detergent Liquid (Hand-Wash)

This COU is referring to the commercial use of HHCB as a chemical substance in cleaning and furnishing care products such as laundry detergent (liquid and granule), fabric enhancers, stain removers, dishwashing detergent (liquid, granule, and hand-wash) products.

EPA has identified HHCB as an ingredient in cleaning and washing products including laundry and dishwashing products, fabric conditioners, laundry additives such as bleaches, hand dishwashing soaps, machine dishwashing soaps, ironing aids, liquid cleaners such as all-purpose and glass cleansers, carpet cleaners, disinfecting wipes, high pressure washer cleaners, automotive care cleaners, and spray cleaners (EPA-HQ-OPPT-2018-0430-0013).

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.13 Commercial Use – Plastic and Rubber Articles

This COU is referring to the commercial use of HHCB as a chemical substance in plastic and rubber articles not covered elsewhere by other COUs.

EPA received public comment that HHCB is incorporated into plastic pellets which are then used to produce scented restroom care articles such as odor eliminating discs and clips, and garbage bags (EPA-HQ-OPPT-2018-0430-0017); (U.S. EPA, 2019a). EPA also identified disposable floor mats (U.S. EPA, 2019a).

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.14 Commercial Use – Other Use – Laboratory Chemicals

This COU refers to the use of HHCB as a laboratory chemical.

EPA has identified approximately three suppliers of HHCB for use as a laboratory chemical being sold in various quantities between 1 g and 1 kg. One public commenter (EPA-HQ-OPPT-2018-0430-0032) provided descriptions of their use of HHCB in analytical standard, research, equipment calibration, and sample preparation applications.

EPA notes that the same applications and methods used for quality control can be applied in industrial and commercial settings.

#### D.1.15 Consumer Use – Air Care Products – Air Fresheners for Motor Vehicles

This COU is referring to the consumer use of HHCB as a chemical substance in air care products, specifically air fresheners for motor vehicles.

HHCB is used as a deodorizer in air fresheners for motor vehicles. These products are typically hung on a vehicle's rearview mirror or clipped on the vehicle's air vents which act as an instant action air freshener. These products differ from the COU *Air care products – Instant action air fresheners*, in that products under this COU are specifically designed and exclusively sold for use in vehicles.

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.16 Consumer Use – Air Care Products – Continuous Action Air Fresheners

This COU is referring to the consumer use of HHCB as a chemical substance in air care products, specifically continuous-action air fresheners. Continuous-action products use a heat source to vaporize the fragrance and release the fragrance gradually and consistently over a longer period.

HHCB is used as a deodorizer in continuous-action air fresheners. These products include solid-room air fresheners, aroma chemicals, and scented candles. Public comments identified HHCB in continuous action air fresheners such as candles, fragrance oils, scented bathroom clips, and air freshener plug-ins (U.S. EPA, 2019a); (EPA-HQ-OPPT-2018-0430-0012).

#### D.1.17 Consumer Use – Air Care Products – Instant Action Air Fresheners

This COU is referring to the consumer use of HHCB as a chemical substance in air care products, specifically instant action air fresheners. Instant action air fresheners are aerosols or atomizers that manually dispense when needed.

Instant action air fresheners include aerosols, carpet and room deodorizers, and pet odor spray.

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.18 Consumer Use – Cleaning and Furnishing Care Products - All-Purpose Foam Spray Cleaner; All-Purpose Liquid Cleaner/Polish; All-Purpose Liquid Spray Cleaner; All-Purpose Waxes and Polishes; Appliance Cleaners; Drain and Toilet Cleaners (Liquid); Powder Cleaners (Floors); Powder Cleaners (Porcelain)

This COU is referring to the consumer use of HHCB as a chemical substance in cleaning and furnishing care products such as all-purpose foam spray cleaners, polishes, liquid spray cleaners, waxes and polishes, appliance cleaners, liquid drain and toilet cleaners, and powder cleaners for floors and porcelain surfaces.

HHCB is an ingredient in bathroom mold and mildew cleaner, carpet and room deodorizing products, multi-surface floor cleaning products, glass cleaning products, and hard surface cleaning products.

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.19 Consumer Use – Laundry and Dishwashing Products - Laundry Detergent (Liquid); Laundry Detergent (Unit Dose/Granule); Fabric Enhancers; Stain Removers; Dishwashing Detergent (Liquid/ Gel); Dishwashing Detergent (Unit Dose/ Granule); Dishwashing Detergent Liquid (Hand-Wash)

This COU is referring to the consumer use of HHCB as a chemical substance in cleaning and furnishing care products such as laundry detergent (liquid and granule), fabric enhancers, stain removers, dishwashing detergent (liquid, granule, and hand-wash) products.

EPA has identified HHCB as an ingredient in cleaning and washing products including laundry and dishwashing products, fabric conditioners, laundry additives such as bleaches, hand dishwashing soaps, machine dishwashing soaps, ironing aids, liquid cleaners such as all-purpose and glass cleansers, carpet cleaners, disinfecting wipes, high pressure washer cleaners, automotive care cleaners, and spray cleaners (EPA-HQ-OPPT-2018-0430-0013).

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.20 Consumer Use – Plastic and Rubber Articles

This COU is referring to the consumer use of HHCB as a chemical substance in plastic and rubber articles not covered elsewhere by other COUs.

EPA received public comment that HHCB is incorporated into plastic pellets which are then used to produce scented restroom care articles such as odor eliminating discs and clips, and garbage bags (EPA-HQ-OPPT-2018-0430-0017); (U.S. EPA, 2019a). EPA also identified HHCB in disposable floor mats (U.S. EPA, 2019a).

EPA expects that these products are likely to be used in both commercial and consumer applications.

#### D.1.21 Consumer Use – Chemical Substances in Treatment Products - Ion Exchangers; Liquid Water Treatment Products; Solid Powder Water Treatment Products

This COU is referring to the consumer use of HHCB in ion exchangers, liquid water treatment products, and solid powder water treatment products.

HHCB is used in lime deposit removers for hot water heaters, and water filtration and treatment products (U.S. EPA, 2020a).

#### D.1.22 Disposal

For purposes of the HHCB risk evaluation, this COU refers to the HHCB in a waste stream that is collected from facilities and households and are unloaded at and treated or disposed at third-party sites. Each of the COUs of HHCB may generate waste streams of the chemical. This COU also encompasses HHCB contained in wastewater discharged by consumers or occupational users to publicly owned treatment works (POTW) or other, non-POTW for treatment, as well as other wastes. HHCB is expected to be released to other environmental media, such as introductions of biosolids to soil or migration to water sources, through waste disposal (*e.g.,* disposal of formulations containing HHCB, plastic and rubber products, and transport containers). Recycling of HHCB and HHCB-containing products is considered a different COU. Environmental releases from industrial sites are assessed in each condition of use and are not included as part of the Disposal COU.

## D.2 Updates to the HHCB Conditions of Use Table

After the release of the final scope document in 2020 (U.S. EPA, 2020c), EPA received updated submissions under the 2020 CDR reported data. In addition to new submissions received under the 2020 CDR, the reporting name codes changed for the 2020 CDR reporting cycle. Therefore, EPA amended the subcategory description of certain HHCB COUs based on those new submissions and new reporting name codes. EPA also removed a COU that was no longer reported in CDR and not reasonably foreseen to be a use of HHCB. Table_Apx D-1 summarizes the changes to the COUs based on the new reporting codes in the 2020 CDR.

**Table_Apx D-1. Additions and Name Changes to Categories and Subcategories of Conditions of Use Based on Updated Reporting in the 2020 CDR**

| Life Cycle Stage and Category | Original Subcategory in the 2020 Scope Document | Occurred Change | Revised Subcategory in the 2025 Risk Evaluation |
|---|---|---|---|
| Commercial use – Cleaning and furnishing care products | Cleaning products, including all-purpose liquid cleaner and bathroom cleaners (including liquid, foam, and spray cleaners) | Name change based on new industry code | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) |
| Commercial use – Laundry and dishwashing products | Laundry products, including liquid laundry detergent and fabric softener | Name change based on new industry code | Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/gel); Dishwashing detergent (unit dose/ granule); Dishwashing detergent liquid (hand-wash) |
| Consumer use – Cleaning and furnishing care products | Cleaning products, including all-purpose liquid cleaner and bathroom cleaners (including liquid, foam, and spray cleaners) | Name change based on new industry code | All-purpose foam spray cleaner; All-purpose liquid cleaner/polish; All-purpose liquid spray cleaner; All-purpose waxes and polishes; Appliance cleaners; Drain and toilet cleaners (liquid); Powder cleaners (floors); Powder cleaners (porcelain) |
| Consumer use – Laundry and dishwashing products | Laundry products, including liquid laundry detergent and fabric softener | Name change based on new industry code | Laundry detergent (liquid); Laundry detergent (unit dose/granule); Fabric enhancers; stain removers; Dry cleaning and associated products; Dishwashing detergent (liquid/ gel); Dishwashing detergent (unit dose/ granule); Dishwashing detergent liquid (hand-wash) |
| Consumer use – Paper products | Paper products | Removed | N/A |

| Life Cycle Stage and Category | Original Subcategory in the 2020 Scope Document | Occurred Change | Revised Subcategory in the 2025 Risk Evaluation |
|---|---|---|---|
| Consumer use – Chemical substances in treatment products | N/A | Addition from 2020 CDR reporting cycle | Ion exchangers; Liquid water treatment products; Solid powder water treatment products |

### D.2.1 Paper Products

This COU was removed from the draft risk evaluation because this use is no longer intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, use, or disposal. This COU was last reported during the 2012 CDR submission cycle by one reporter. Additionally, EPA further investigated the paper articles associated with this COU and determined that HHCB is not found in these types of articles. EPA therefore concluded that HHCB for uses in paper products and articles is not reasonably foreseen.

### D.2.2 Ion Exchangers; Liquid Water Treatment Products; Solid Powder Water Treatment Products

This COU was included in this draft risk evaluation because EPA received new information through the 2020 CDR report that HHCB is intended, known, or reasonably foreseen to be used as a fragrance in lime deposit removers, associated with this COU (U.S. EPA, 2020a).

# Appendix E PRODUCT DATA

Table_Apx E-1 includes the concentration data identified for HHCB in various product types. Commercial and consumer product-specific searches were conducted to identify SDSs and ingredient disclosures for HHCB, which are documented in the HHCB Product Concentration Dataset (U.S. EPA, 2025b). All identified products were on the U.S. market as of April 2025. Some products had public ingredient disclosure forms indicating HHCB as an ingredient, but no concentration data was available.

**Table_Apx E-1. Products Containing HHCB and the Weight Concentrations**

| Product Type | Specific Types of Products | Number of Commercial Products | Number of Consumer Products | Range of HHCB Weight Concentrations[a] |
|---|---|---|---|---|
| Air fresheners for motor vehicles | Vent clips, paper, hanging, jar, can or spray air fresheners | 12 | 15 | <1 to 12.5% |
| Continuous action air fresheners | Metered spray air fresheners, air freshener diffusers, plug-ins, wax melts, candles, plastic clips, toilet bowl deodorizer, floor mat, rim cages and urinal screens | 26 | 10 | <0.01 to 10% |
| Instant action air fresheners | Aerosol/spray air fresheners, odor eliminating discs, liquid or powder deodorizer, and autoclave deodorizer (discontinued) | 21 | 16 | <0.1 to 5% |
| All-purpose foam spray cleaner | Bathroom cleaner | 1 | 1 | NR |
| All-purpose liquid cleaner/polish | Bath/washroom cleaner, floor cleaner, carpet cleaner, floor polish, hard-surface cleaner, and glass cleaner | 12 | 6 | <0.1 to 0.3% |
| All-purpose liquid spray cleaner | Hard-surface cleaner, furniture cleaner, and bathroom cleaner | 1 | 2 | <0.1% |
| All-purpose waxes and polishes | Car polish, granite and stone polish, wood oil, and wood polish | 1 | 3 | NR |
| Appliance cleaners | None found | 0 | 0 | NR |
| Drain and toilet cleaners (liquid) [b] | Bathroom cleaner | * | 0 | * |
| Powder cleaners (floors) | None found | 0 | 0 | NR |
| Powder cleaners (porcelain) | None found | 0 | 0 | NR |
| Laundry detergent (liquid) | Laundry detergents, and scent boosters | 0 | 20 | ≤0.1% |

| Product Type | Specific Types of Products | Number of Commercial Products | Number of Consumer Products | Range of HHCB Weight Concentrations[a] |
|---|---|---|---|---|
| Laundry detergent (unit dose/granule) | Powder laundry detergents, laundry packs/pacs/unit doses | 1 | 11 | 0.01 to 0.9% |
| Fabric enhancers | Scent/odor boosters, fabric softeners, dryer sheets, clothing refresher mist, washing machine cleaner, and other laundry products | 2 | 16 | <0.1 to <1% |
| Stain removers | Stain remover (liquid and foam), gel sticks, and pre-spotters | 1 | 13 | ≥0.1 to <1% |
| Dishwashing detergent (liquid/ gel) | None found | 0 | 0 | NR |
| Dishwashing detergent (unit dose/granule) | None found | 0 | 0 | NR |
| Dishwashing detergent liquid (hand-wash) | Dish + hand soap | 0 | 1 | <0.1% |
| Laboratory chemicals | Laboratory chemical at varying concentrations | 5 | 0 | 0.0% to ≤100% |

NR = not reported
[a] Only weight concentrations included are products deemed to be "high" quality (*i.e.,* no issues identified)
[b] Some of the commercial all-purpose liquid cleaner/polish are also marketed as toilet cleaners.

# Appendix F POPULATION ADJUSTED CASE STUDY FOR COMMERCIAL RELEASES

## F.1 Census Information on U.S. Businesses

Census information on U.S. businesses was used to generate per capita estimate for businesses expected to be primary contributors to the release of HHCB down-the-drain from cleaning, laundry care, and dishwashing products (Table_Apx F-1). The total number of establishments for each NAICS codes was taken from the U.S. Census Statistics on Businesses; this total was used to generate per capita rates based on the total population in the United States.

**Table_Apx F-1. Census Information on U.S. Businesses Expected to be Contributors to HHCB Releases**

| Businesses | NAICS Code | Products Used | Total Number of Establishments in U.S. (2023) | U.S. Average per Capita (per 10k) |
|---|---|---|---|---|
| **Cleaning Services** | | | **73,494** | **2.22** |
| Janitorial Services | 561720 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner | 66,471 | 2.01 |
| Carpet and Upholstery Cleaning Services | 561740 | Carpet Cleaner | 7,023 | 0.21 |
| **Hospitals and Nursing Facilities** | | | **102,640** | **3.10** |
| General Medical and Surgical Hospitals | 622110 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 5,849 | 0.18 |
| Psychiatric and Substance Abuse Hospitals | 622210 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 795 | 0.02 |
| Specialty (except Psychiatric and Substance Abuse) Hospitals | 622310 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 821 | 0.02 |
| Nursing Care Facilities (Skilled Nursing Facilities) | 623110 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 17,692 | 0.53 |
| Residential Intellectual and Developmental Disability Facilities | 623210 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 36,315 | 1.10 |

| Businesses | NAICS Code | Products Used | Total Number of Establishments in U.S. (2023) | U.S. Average per Capita (per 10k) |
|---|---|---|---|---|
| Residential Mental Health and Substance Abuse Facilities | 623220 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 8,416 | 0.25 |
| Continuing Care Retirement Communities | 623311 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 5,420 | 0.16 |
| Assisted Living Facilities for the Elderly | 623312 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 21,265 | 0.64 |
| Other Residential Care Facilities | 623990 | Toilet Cleaner, Surface Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 6,067 | 0.18 |
| **Lodgings** | | | **62,947** | **1.90** |
| Hotels (except Casino Hotels) and Motels | 721110 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 56,478 | 1.70 |
| Casino Hotels | 721120 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 478 | 0.01 |
| Bed-and-Breakfast Inns | 721191 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 2,554 | 0.08 |
| All Other Traveler Accommodation | 721199 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 1,771 | 0.05 |
| Rooming and Boarding Houses, Dormitories, and Workers' Camps | 721310 | Toilet Cleaner, Surface Cleaner, Carpet Cleaner, Laundry Detergent-Institutional, Laundry Softener-Institutional | 1,666 | 0.05 |
| **Food Service** | | | **675,135** | **20.37** |

| Businesses | NAICS Code | Products Used | Total Number of Establishments in U.S. (2023) | U.S. Average per Capita (per 10k) |
|---|---|---|---|---|
| Food Service Contractors | 722310 | Dishwasher Detergent, Dish Soap (Hand) | 29,474 | 0.89 |
| Caterers | 722320 | Dishwasher Detergent, Dish Soap (Hand) | 12,800 | 0.39 |
| Mobile Food Services | 722330 | Dishwasher Detergent, Dish Soap (Hand) | 10,134 | 0.31 |
| Drinking Places (Alcoholic Beverages) | 722410 | Dishwasher Detergent, Dish Soap (Hand) | 38,398 | 1.16 |
| Full-Service Restaurants | 722511 | Dishwasher Detergent, Dish Soap (Hand) | 250,186 | 7.55 |
| Limited-Service Restaurants | 722513 | Dishwasher Detergent, Dish Soap (Hand) | 256,375 | 7.73 |
| Cafeterias, Grill Buffets, and Buffets | 722514 | Dishwasher Detergent, Dish Soap (Hand) | 4,783 | 0.14 |
| Snack and Nonalcoholic Beverage Bars | 722515 | Dishwasher Detergent, Dish Soap (Hand) | 72,985 | 2.20 |
| **Laundries** | | | **19,234** | **0.58** |
| Drycleaning and Laundry Services (except Coin-Operated) | 812320 | Laundry Detergent-Industrial, Laundry Softener-Industrial | 16,906 | 0.51 |
| Linen Supply | 812331 | Laundry Detergent-Industrial, Laundry Softener-Industrial | 830 | 0.03 |
| Industrial Launderers | 812332 | Laundry Detergent-Industrial, Laundry Softener-Industrial | 1,498 | 0.05 |

# Appendix G DRAFT OCCUPATIONAL EXPOSURE VALUE DERIVATION AND ANALYTICAL METHODS USED TO DETECT HHCB

EPA has calculated an 8-hour time-weighted average (TWA) existing chemical occupational exposure value (OEV) to summarize the occupational exposure scenario and sensitive health endpoints into a single value. This calculated value could be used to support risk management efforts for HHCB under TSCA section 6(a), 15 U.S.C. 2605. EPA calculated the value rounded to 0.244 ppm (2.58 mg/m$^3$) for inhalation exposures to HHCB as an 8-hour TWA and for consideration in workplace settings (see Appendix G.1) based on the intermediate non-cancer human equivalent concentration (HEC) for decreased offspring bodyweight.

TSCA requires risk evaluations to be conducted without consideration of cost and other non-risk factors, and thus this most sensitive occupational exposure value represents a risk-only number. If risk management for HHCB is implemented following the final risk evaluation, EPA may consider cost and other non-risk factors, such as technological feasibility, the availability of alternatives, and the potential for critical or essential uses. Any existing chemical exposure limit (ECEL) used for occupational safety risk management purposes could differ from the OEV presented in this appendix based on additional consideration of exposures and non-risk factors consistent with TSCA section 6(c).

The calculated value for HHCB represents the exposure concentration below which exposed workers and occupational non-users are not expected to exhibit any appreciable risk of adverse toxicological outcomes. This value accounts for potentially exposed and susceptible subpopulations (PESS). The value is derived based on the most sensitive human health effect (*i.e.,* developmental toxicity) supported by the weight of scientific evidence. This value is expressed relative to benchmarks and standard occupational scenario assumptions of 8 hours per day, 5 days per week exposures for a total of 250 days exposure per year, and a 40-year working life.

All hazard values used in these calculations are based on the non-cancer point of departure (POD) for intermediate and chronic exposure durations from 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, 2026y).

EPA expects that at the most sensitive occupational exposure value of 0.244 ppm (2.58 mg/m$^3$) for intermediate exposure, workers, and occupational non-users would also be protected against health effects from acute and chronic occupational exposures, including any for potential cancer effects (see Appendix G.1 for details). EPA has not separately calculated a short-term occupational exposure value (STEV) for HHCB because the Agency determined that HHCB is not acutely hazardous; thus, there is no concern for effects following short term exposure at 15-minute concentrations.

Of the identified occupational monitoring data for HHCB, measured workplace air concentrations were below the calculated exposure value. No available monitoring methods were identified from the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). OSHA has not set a permissible exposure limit (PEL) as an 8-hour TWA for HHCB (https://www.osha.gov/annotated-pels; accessed March 22, 2026). There are no NIOSH-recommended exposure limits (RELs) or American Conference of Governmental Industrial Hygienists (ACIGH) threshold limit values (TLVs) for HHCB.

## G.1 Occupational Exposure Value Calculations

This section presents the calculations used to estimate the OEVs using inputs derived in this risk evaluation. For HHCB, the most sensitive occupational exposure value is based on decreased offspring bodyweight following intermediate exposure and the resulting 8-hour TWA is rounded to 0.244 ppm. The human health hazard values (human equivalent concentrations [HECs]) used in the equations are derived 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, 2026y).

***Most Sensitive Occupational Exposure Value (Intermediate Non-Cancer)***

The intermediate occupational exposure value ($EV_{intermediate}$) was calculated as the concentration at which the intermediate MOE would equal the benchmark MOE for intermediate occupational exposure using the following equation:

$$EV_{intermediate} = \frac{HEC_{intermediate}}{Benchmark\ MOE_{intermediate}} * \frac{AT_{HEC\ intermediate}}{ED*EF} * \frac{IR_{resting}}{IR_{workers}}$$

$$= \frac{3.65\ \text{ppm}}{30} * \frac{24h/d * 30d}{8h/d * 22d} * \frac{0.6125\ \text{m}^3/hr}{1.25\ \text{m}^3/hr} = 0.244\ \text{ppm}$$

$$EV_{intermediate}\left(\frac{\text{mg}}{\text{m}^3}\right) = \frac{EV\ ppm\ * MW}{Molar\ Volume} = \frac{0.244\ \text{ppm} * 258.4\frac{g}{mol}}{24.45\ \frac{L}{mol}} = 2.58\ \frac{\text{mg}}{\text{m}^3}$$

***Acute Non-Cancer Occupational Exposure Value***

EPA did not derive an acute non-cancer POD for HHCB. Therefore, no corresponding OEV is calculated.

***Chronic Non-Cancer Occupational Exposure Value***

The hazard value (an HEC of 3.65 ppm) is the same for the intermediate and chronic OESs. EPA has determined that because the same critical health effect applies to both intermediate and chronic exposure contexts, the relevant averaging time should be considered equivalent across both exposure scenarios. Therefore, the resulting $EV_{chronic}$ would be the same as the $EV_{intermediate}$ based on intermediate exposures and EPA is presenting only the $EV_{intermediate}$.

***Lifetime Cancer Occupational Exposure Value***

EPA did not derive a cancer POD for HHCB. Therefore, no corresponding OEV is calculated.

The parameters used in the above equations are described here. Numerical values chosen for the parameters are described in relevant sections of this draft risk evaluation and the *Draft Human Health and Environmental Hazard Assessment for HHCB* (U.S. EPA, 2026y).

Where:

$AT_{HECchronic}$ = Averaging time for the POD/HEC used for evaluating non-cancer, chronic occupational risk, based on study conditions and/or HEC adjustments (24 h/day for 365 days/yr) and assuming the number of years matches the high-end working years (WY, 40 yrs) for a worker

$AT_{HECintermediate}$ = Averaging time for the POD/HEC used for evaluating non-cancer, intermediate occupational risk, based on study conditions and/or any HEC adjustments (24 h/day for 30 days)

$AT_{HECacute}$ = Averaging time for the POD/HEC used for evaluating non-cancer, acute occupational risk, based on study conditions and/or any HEC adjustments (24 h/day)

$AT_{IUR}$ = Averaging time for the cancer IUR, based on study conditions and any adjustments (24 h/day for 365 days/yr) and averaged over a lifetime (78 yrs)

Benchmark $MOE_{intermediate}$ = Intermediate non-cancer benchmark margin of exposure, based on the total uncertainty factor of 30

$Benchmark_{cancer}$ = Benchmark for excess lifetime cancer risk

$EV_{intermediate}$ = Draft occupational exposure value based on decreased offspring bodyweight

ED = Exposure duration (8 h/day)

EF = Exposure frequency (1 day/yr for acute, 22 days/yr for intermediate, 250 days/yr for chronic and lifetime)

$HEC_{acute,\ intermediate,\ or\ chronic}$ = Human equivalent concentration for acute, intermediate, or chronic occupational exposure scenarios

IUR = Inhalation unit risk (per mg/m$^3$ and per ppm)

IR = Inhalation rate (default is 1.25 m$^3$/h for workers and 0.6125 m$^3$/h for the general population at rest)

WY = Working years per lifetime at the 95th percentile (40 yrs)

Molar Volume = 24.45 L/mol, the volume of a mole of gas at 1 atm and 25 °C

MW = Molecular weight of HHCB (258.4 g/mole)

Unit conversion:

1 ppm = 10.57 mg/m$^3$ (based on the molecular weight of 258.4 g/mol for HHCB)