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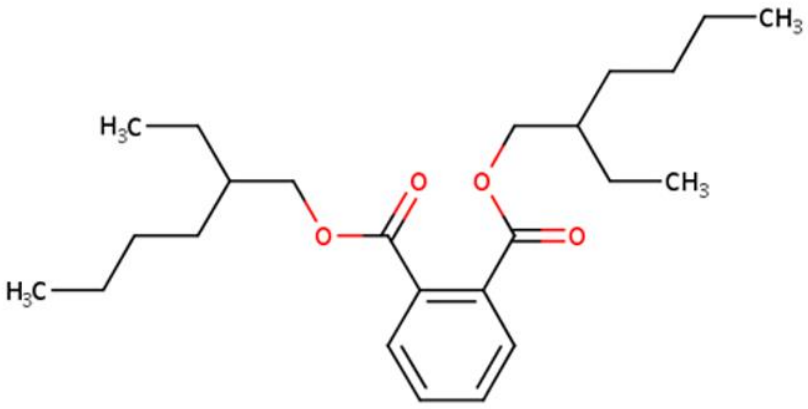
Consumer and Indoor Exposure Assessment for Diethylhexyl Phthalate (DEHP)

Technical Support Document for the Risk Evaluation

CASRN 117-81-7



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KEY ABBREVIATIONS AND ACRONYMS

ACC	American Chemical Council
ACC HPP	American Chemistry Council's High Phthalates Panel
ADD	Average daily dose
ADR	Acute dose rate
CADD	Chronic average daily dose
CASRN	Chemical Abstracts Search Registry Number
CDC	Centers for Disease Control and Prevention (U.S.)
CDR	Chemical Data Reporting
CEM	Consumer Exposure Model
CPSC	Consumer Product Safety Commission (U.S.)
CPSIA	Consumer Product Safety Improvement Act (U.S.)
COU	Condition of use
DBP	Dibutyl phthalate
DEHP	Diethylhexyl phthalate, Diisononyl phthalate
DIY	Do-it-yourself
EPA	Environmental Protection Agency (U.S.)
K_{OA}	Octanol-air partition coefficient
MCCEM	Multi-Chamber Concentration and Exposure Model
MOE	Margin of exposure
MSDS	Material safety data sheets
NHANES	National Health and Nutrition Examination Survey
OCSPP	Office of Chemical Safety and Pollution Prevention (EPA)
OPPT	Office of Pollution Prevention and Toxics (EPA)
PVC	Polyvinyl chloride
SDS	Safety data sheet
SVOC	Semi-volatile organic compound
TSCA	Toxic Substances Control Act
TSD	Technical support document
U.S.	United States
w/w	Weight per weight

SUMMARY

DEHP – Consumer Exposure Assessment Summary:
Key Points

EPA (or the Agency) evaluated human exposure to for diethylhexyl phthalate (DEHP) in consumer products resulting from conditions of use (COUs) as defined under the Toxic Substances Control Act (TSCA). These included solid articles such as air beds, car mats, synthetic leather furniture and clothing, vinyl flooring, wallpaper, shower curtains, insulated cords, mobile phone covers, erasers, and children's toys; liquid products including adhesives, sealants, and paints; and coatings.

Exposure Approaches and Methodology Key Points (Section 2)

- The major routes of exposure considered were ingestion via mouthing, ingestion of suspended dust, ingestion of settled dust, inhalation, and dermal exposure.
- The exposure durations considered were acute, intermediate, and chronic.
- Intermediate exposures were calculated from the Consumer Exposure Model (CEM) daily exposure outputs for applicable scenarios in a spreadsheet outside of CEM.
- For inhalation and ingestion exposures, EPA used the CEM to estimate acute and chronic exposures to consumer users and bystanders (Section 2.2).
- Dermal exposures for both liquid products and solid articles were calculated using a flux-limited, dermal absorption approach (Section 2.3).

Exposure Dose Results Key Points (Section 3)

- Across all routes, ingestion of DEHP had the overall second highest doses for articles assessed for mouthing, such as toys, furniture, wire insulation, and rubber erasers.
- The highest exposures estimated for all lifestages from infant to adult were for dermal exposure to indoor scenario articles such as air mattresses. For teens and adults, dermal contact was a strong driver of DEHP exposure.

This technical support document (TSD) accompanies the TSCA *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h). It provides detailed descriptions of DEHP consumer uses and indoor exposure assessments. DEHP is the diester of phthalic acid and the branched-chain 2-ethylhexanol (CASRN 117-81-7) and is primarily used as a plasticizer in polyvinyl chloride (PVC) in consumer, commercial, and industrial applications—though it is also used in adhesives, sealants, paints, coatings, rubbers, and plastics as well as for other applications. It is added to certain products because its large molecular size and strongly hydrophobic chemical structure result in waterproof qualities in finished goods. As such, products containing DEHP tend to be specialized in their intended use. For instance, all caulking compounds identified with DEHP were intended for outside use or high moisture indoor environments, and all spray paints identified were for waterproofing metal and wood surfaces.

This assessment considers human exposure to DEHP in consumer products resulting from COUs under the Toxic Substances Control Act (TSCA). The major routes of exposure considered were ingestion via mouthing, ingestion of suspended dust, ingestion of settled dust, inhalation, and dermal exposure. The exposure durations considered were acute, intermediate, and chronic. Acute exposures are for an exposure duration of 1 day, chronic exposures are for a duration of 1 year, and intermediate exposures are for a duration of 30 days.

For inhalation and ingestion exposures, EPA used CEM to estimate acute and chronic exposures to consumer users and bystanders. Intermediate exposures were calculated from the CEM daily exposure outputs for applicable scenarios in a spreadsheet Consumer Risk Calculator (DCHP) (U.S. EPA, 2025d) outside of CEM because the exposure duration for intermediate scenarios is outside the 60-day modeling period CEM uses. For each scenario, low-, medium-, and high-exposure scenarios were developed in which values for duration of use, frequency of use, and surface area were determined based on reasonably available information and professional judgment (see Section 2.2.3 for CEM parameterization and input selection).

Overall, confidence in the CEM inhalation and ingestion modeling estimates were robust to moderate depending on product or article scenario (see Section 5.1). In brief, CEM default scenarios were selected for mass of product used, duration of use, and frequency of use. Generally, EPA has robust confidence when using CEM defaults. When no CEM default was available or applicable for some products, manufacturer instructions and online retailers provided details on recommended use of the product (*e.g.,* mass of product used during product application), see Section 2.2.3. For most inhalation and ingestion product use patterns, overall confidence was robust because the supporting evidence provided product-specific information. For articles, key parameters that control DEHP emission rates for CEM models are weight fraction of DEHP in the material, density of article material, article surface area, and surface layer thickness. For most articles that did not have default CEM inputs, EPA's *Exposure Factors Handbook* (U.S. EPA, 2011c) or professional judgment was used to select the duration of use and article surface area for the low-, medium-, and high-exposure scenario levels.

Most inhalation and ingestion article use patterns overall confidence was rated robust because the source of the information was either the *Exposure Factors Handbook* (also referred to as "the Handbook") (U.S. EPA, 2011c), or when using professional judgment, EPA based selection of inputs on online article descriptions for article surface area (Section 2.2.3). The Agency has moderate confidence in ingestion via mouthing estimates due to uncertainties about professional judgment inputs regarding mouthing durations for adult toys as well as synthetic leather furniture for children. In addition, the chemical migration rate input parameter has a moderate confidence due to the large variability in the empirical data used in this assessment and unknown correlation between chemical migration rate and DEHP concentration in articles.

Dermal exposures for both liquid products and solid articles were calculated in a spreadsheet outside of CEM; see *Consumer Exposure Analysis for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025d). CEM dermal modeling assumes infinite DBP migration from product to skin without considering saturation, which would result in an overestimation of dose and subsequent risk (see Section 2.3 for a detailed explanation). Low-, medium-, and high-exposure scenarios were developed for each product and article scenario by varying values for duration and frequency of dermal contact and area of exposed skin.

Confidence in the dermal exposure estimates were moderate due to uncertainties associated with the dermal absorption literature. The flux-limited screening dermal absorption approaches for liquid and solid products and articles assumes an excess of DEHP in contact with the skin independent of DEHP concentration in the article/product. The flux-limited screening approach provides an upper bound of dermal absorption of DEHP and likely results in some overestimations; see Section 5.1 for detailed discussion on limitations, strengths, and confidence in dermal estimates. In brief, inputs for duration of dermal contact were either from the *Exposure Factors Handbook* or professional judgment based on product and article manufacturer use descriptions. For products, manufacturer instructions provided details on recommended use of the product (*e.g.,* adhesives and sealants). However, for articles, typically such data are not available from manufacturers. Sometimes inputs were found in the Handbook

(*e.g.,* vinyl flooring contact duration), otherwise, professional judgment was used (*e.g.,* length of time an individual spends sitting on a couch per day for medium- and low-intensity use scenarios).

Inhalation, ingestion, and dermal doses of DEHP for new and legacy children's toys generally differed slightly—primarily due to a difference of one to three orders of magnitude in the weight fractions despite all other input parameters being the same for the children's toys modeled, which is a noteworthy characteristic to consider when estimating risks. Under the Consumer Product Safety Improvement Act of 2008 (CPSIA), Congress permanently prohibited the sale of children's toys or child-care articles containing concentrations of more than 0.1 percent of certain phthalates.

However, it is possible that some individuals may still have children's toys in the home that were produced before statutory and regulatory limitations established by CPSIA section 108(a) (see also 16 CFR 1307.3(a)). The highest exposures estimated for all lifestages from infant to adult were for dermal exposure to indoor scenario articles such as air mattresses. Specifically for teens and adults, dermal contact was a strong driver of DEHP exposure. Across all routes, ingestion of DEHP had the overall second highest doses for articles assessed for mouthing, such as toys, furniture, wire insulation, and rubber erasers. Because mouthing tendencies decrease or cease entirely for children aged 6 to 10 years, exposure from mouthing is expected to be larger for infants to 5-year-old children. Products/articles that did not have a mouthing estimate are not expected to have direct mouthing exposures; thus, the ingestion exposure estimates fall below all other exposure routes.

Inhalation of DEHP-contaminated dust is an important contributor to indoor exposures. However, inhalation exposures were generally lower compared to dermal and ingestion exposures, with the highest inhalation exposures coming from furniture textiles.

1 INTRODUCTION

DEHP is the diester of phthalic acid and the branched-chain 2-ethylhexanol (CASRN 117-81-7). DEHP is primarily used as a plasticizer in PVC in consumer, commercial, and industrial applications, though it is also used in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as for other applications.

EPA assembled information from 2016 and 2020 data reported in the Chemical Data Reporting (CDR) database and consulted a variety of other sources, including published literature, company websites, and government and commercial trade databases and publications to identify COUs under TSCA for DEHP relevant to consumer exposures (see Table 1-1). Weight fractions of DEHP in specific items were gathered from the same sources, and these data were used in this assessment in a tiered approach as described in Section 2.1.

The migration of DEHP from consumer products and articles has been identified as a potential mechanism of exposure. However, the relative contribution of various consumer goods to overall exposure to DEHP has not been well characterized. The identified uses can result in exposures to both consumers and bystanders (non-product users that are incidentally exposed to the product). For all the DEHP-containing consumer products identified, the approach involves addressing the inherent uncertainties by modeling low-, medium-, and high-exposure scenarios. Due to the lack of comprehensive data on various parameters and the expected variability in exposure pathways, these scenarios allow for a robust exploration of the estimated risks associated with DEHP across COUs and various age groups.

Because PVC products are ubiquitous in modern indoor environments, and since DEHP is not chemically-bound to many consumer products and articles in which it is incorporated, it can leach, migrate, or evaporate into indoor air and concentrate in household dust. Exposure to compounds through dust ingestion, dust inhalation, and dermal absorption is a particular concern for young children between the ages of 6 months and 2 years. This is because their behavior, such as crawling and placing their hands and other objects in their mouth, increases hand-to-dust contact. Estimated exposures were assessed and compared for children of all ages.

Table 1-1. Consumer Conditions of Use Table

Life Cycle Stage [a]	Category	Subcategory [b]	Reference(s)
Consumer Use	Automotive, fuel, agriculture, outdoor use products	Lawn and garden care products	(U.S. EPA, 2020)
	Construction, paint, electrical, and metal products	Adhesives and sealants	(U.S. Chemical & Plastics, 2020; U.S. EPA, 2020)
		Batteries	(Kastar, 2024; SPYPOINT, 2024; Thumper, 2024)
		Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	(U.S. EPA, 2020; Hsu et al., 2017)
		Machinery, mechanical appliances, electrical/electronic articles	(U.S. EPA, 2019a; Just In Time Chemical, 2015)
		Paints and coatings	(U.S. EPA, 2020; Sherwin Williams, 2019; U.S. EPA, 2019a; Eagle, 2015a, b)
	Furnishing, cleaning, and treatment care products	Fabric, textile, and leather products; furniture and furnishings	(EquiFit, 2024; KINCO, 2024; Mandal et al., 2022; U.S. EPA, 2019a)
		Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles; fabrics, textiles, and apparel	(U.S. EPA, 2020; WECork, 2001)
	Packaging, paper, plastic, toys, hobby products	Ink toner, and colorants	(Identity Group, 2016a)
		Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	(Quad City Safety Inc, 2024a, b; WA DOE, 2021; U.S. EPA, 2020, 2019a; BriteLine, 2018); EPA-HQ-OPPT-2018-0433-0004
		Packaging (excluding food packaging), including paper articles	(U.S. EPA, 2020)
		Toys, playground, and sporting equipment	(Armada et al., 2022; U.S. EPA, 2019b)
Consumer Use	Other	Novelty articles	(Stabile, 2013)
		Automotive articles	(Westin, 2024; Armada et al., 2022; Reddam and Volz, 2021; U.S. EPA, 2019b); EPA-HQ-OPPT-2019-0131
Disposal	Disposal	Disposal	

[a] Life Cycle Stage Use Definition (40 CFR 711.3) – "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.
[b] These subcategories reflect more specific COUs of DEHP.

2 CONSUMER EXPOSURE APPROACH AND METHODOLOGY

The main steps in performing a consumer exposure assessment are summarized below:

1. Identification and mapping of product and article examples following the consumer COU table (Table 1-1), product, and article identification.
2. Compilation of products and articles manufacturing use instructions to determine patterns of use.
3. Selection of exposure routes and exposed populations according to product/article use descriptions.
4. Identification of data gaps and further search to fill gaps with studies, chemical surrogates or product and article proxies, or professional judgment.[1]
5. Selection of appropriate modeling tools based on available information and chemical properties.
6. Gathering of input parameters per exposure scenario.
7. Parameterization of selected modeling tools.

Consumer products or articles containing DEHP were matched with TSCA COUs appropriate for the anticipated use of the item. Table 2-2 summarizes the consumer exposure scenarios by COU for each product example(s), the relevant exposure routes modeled, an indication of scenarios used in the indoor dust assessment, and whether the analysis was done qualitatively or quantitatively. A quantitative analysis consists of some sort of model or calculated estimate approach and is typically used when sufficient data (*e.g.*, physical and chemical properties, monitoring data, existing assessments) are available for the relevant exposure scenario.

A qualitative analysis consists of a series of logical statements and is typically used when there is data showing that a given exposure scenario would lead to low to insignificant exposures or when there is insufficient data to support the assessment of a particular exposure scenario. Therefore, quantitative assessments were not conducted when the qualitative analysis indicated low to insignificant exposure and/or risk potential. The indoor dust assessment uses consumer product information for selected articles with the goal of recreating the indoor environment. The subset of consumer articles included in the indoor dust assessment were selected for their potential to have large surface areas for dust collection.

For the DEHP consumer exposure assessment, a quantitative analysis was conducted when the exposure route was deemed relevant based on product or article use description and there was sufficient data to parameterize the model. The qualitative analysis is a discussion of exposure potential based on physical and chemical properties, and/or available monitoring data, if available. When a quantitative analysis was conducted, exposure from the consumer COUs was estimated by modeling. Each product or article was individually assessed to determine whether all or some exposure routes were applicable, and approaches were developed accordingly.

Exposure via inhalation and ingestion routes were modeled using EPA's Consumer Exposure Model (CEM) Version 3.2 (U.S. EPA, 2023) for all items aside from tire crumb rubber. Because CEM does not have capabilities to model exposure to chemicals in particulate matter other than indoor dust, all exposure estimates for tire crumb rubber were calculated using a computational framework implemented within a spreadsheet, as described in Section 2.4. Dermal exposure to DEHP-containing consumer products was estimated using a computational framework implemented within a spreadsheet. Refer to

[1] *Professional judgement* as referenced throughout this TSD refers to the utilization of the best available data or information to assess a population, route, or pathway for consumer or indoor dust exposures—especially where substantial data gaps and/or uncertainties are present. This involves conducting supplemental research to address the identified data gaps or uncertainties, including a consideration of concurrent or previous experience with similar assessments, product, or article manufacturer use descriptions, as well as realistic product and article use patterns according to the most recently available literature.

Section 2.3 for a detailed description of dermal uptake modeling, consumer-specific dermal modeling parameters, and assumptions for exposure estimates. Where possible, EPA used the 10th percentile, average, and 95th percentile values for input parameters deemed to characterize a high level of uncertainty and/or variability (*e.g.*, DEHP weight fraction, article surface area, mass of product used, etc.) to characterize low-, medium-, and high-exposure for a given condition of use. If only a range of input parameters (*e.g.*, weight fraction) was reported, EPA used the minimum and maximum of the range for the low- and high-intensity use exposure scenario values, with the average of the minimum and maximum used for the medium-intensity use exposure scenario. All CEM and dermal spreadsheet inputs, sources of information, assumptions, and exposure scenario descriptions are available in the *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025d) and *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e). High-, medium-, and low-intensity use exposure scenarios serve as a two-pronged approach. First, it provides a sensitivity analysis with insight on the impact of the main modeling input parameters (*e.g.*, skin contact area, duration of contact, and frequency of contact) in the doses and risk estimates. And second, the high-intensity use exposure scenarios are used first to screen for potential risks at the upper bound of possible exposures and to refine if needed. Throughout this assessment/TSD, the consumer-related spreadsheets, and risk evaluation, the reporting order is high-, medium-, and low-intensity use exposure scenarios.

Based on reasonably available information from the systematic review process on consumer conditions of use and indoor dust DEHP concentrations, inhalation of DEHP is possible through inhalation of DEHP emitted from products and articles as well as DEHP sorbed to indoor dust and particulate matter. A detailed discussion of indoor dust references, sources, and concentrations is available in Section 4. Because of DEHP's low volatility, there is expected to be low gas-phase inhalation exposures. However, DEHP's physical and chemical properties, such as low vapor pressure, low solubility, and high octanol-air partition coefficient (K_{OA}), suggest a high affinity for organic matter, which is typically present in household dust. The likelihood of sorption to suspended and settled dust is supported by indoor monitoring data. Section 4 reports concentrations of DEHP in settled dust from indoor environments. Due to the presence of DEHP in indoor dust, inhalation and ingestion of suspended dust and ingestion of settled dust are both considered as exposure routes in this consumer assessment.

Based on reasonably available information from the systematic review of consumer conditions of use and indoor dust studies, oral exposure to DEHP is also possible through incidental ingestion during product use, transfer of chemical from hand-to-mouth, or mouthing of articles. Dermal exposure may occur via direct contact with liquid products and solid articles during use. Based on these potential sources and pathways of exposures that may result from the conditions of use identified for DEHP, oral, dermal, and inhalation exposures to consumers and inhalation exposures to bystanders were assessed.

Qualitative analyses describing low exposure potential are presented in Section 2.1, Table 2-2, and Table 2-3—mainly based on physical and chemical properties or product and article use descriptions. For example, given the low volatility of DEHP, emissions to air from solid articles are expected to be relatively low. As such, articles with a small surface area (less than ≈1 m^2) and articles used outdoors were not assessed for inhalation exposure. For items with small surface area for emissions and dust collection, the potential for emission to air and dust is further reduced. To verify test assumptions, a CEM trial run for a generic 1 m^2 item with 30 percent DEHP content by weight was conducted. The combined doses from inhalation and dust ingestion ranged four orders of magnitude less than the point of departure (POD) used to assess human health risk in this assessment and are likely to be negligible as compared to potential exposure by dermal and mouthing routes, both of which were assessed according to the appropriate exposure scenario see *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h). Similarly, solid articles not expected to be mouthed (*e.g.*, building materials, outdoor furniture)

were not assessed for mouthing exposure. Furthermore, as DEHP is a low volatility solid that is used primarily as a plasticizer in manufacturing, potential take-home exposures are likely small in comparison to the scenarios considered in this assessment; thus, take-home exposures were not further explored.

EPA assessed acute (Appendix A.1), chronic (Appendix A.2), and intermediate (Appendix A.3) exposures to DEHP from consumer COUs. For the acute dose rate calculations, an averaging time of 1 day is used, representing the maximum time-integrated dose over a 24-hour period during the exposure event. The chronic dose rate is calculated iteratively at a 30-second interval during the first 24 hours and every subsequent hour for 60 days. Professional judgment and product use descriptions were used to estimate events per day and per month for the calculation of the intermediate dose. See Section 2.4 for intermediate exposures input parameters and assumptions. Whenever professional judgment was used, EPA provided a rationale and description of selected parameters.

2.1 Products and Articles with DEHP Content

Products are generally consumable liquids, aerosols, or semi-solids that are used a given number of times before they are exhausted. Articles are generally solids, polymers, foams, metals, or woods that are present within indoor environments for the duration of their useful life, which may span several years. The preferred data sources for DEHP content in U.S. consumer goods were (1) safety data sheets (SDSs) for specific products or articles with reported DEHP content, (2) peer-reviewed literature providing measurements of DEHP in consumer goods purchased in the United States, and (3) government reports originating in the United States with manufacturer-reported concentrations. In instances where these data from preferred sources were not available, DEHP content in specific products and articles provided in peer-reviewed literature and government reports originating from Canada, the European Union, and Japan were used. Because manufacturing practices and regulations for DEHP in consumer goods are comparable between these regions and the United States, it is reasonable to assume that similarly formulated products may be available across all of these nations/regions. DEHP weight fractions reported in the CDR database were not used as the weight fraction data reported in the CDR database may pertain to a finished good in the product category reported, or it could represent a chemical additive that will be added to other components during the manufacturing process of the finished good.

EPA further evaluated the products and articles identified to ensure that data was representative of items that may expose U.S. consumers to DEHP. Where possible, SDSs were cross-checked with company websites to ensure that each product could reasonably be purchased by consumers. In instances where a product or article could not be purchased by a consumer, EPA did not evaluate the item in a do-it-yourself (DIY) or application scenario but did determine whether consumers might reasonably be exposed to the specific item as part of a purchased good, including homes and automobiles. Phthalate limits established by statutes and regulations, such as CPSIA section 108(a) and 16 CFR 1307.3(a), were taken into consideration when reviewing data reported in literature and government reports in determining whether data were likely to be relevant to the current U.S. consumer market. For solid articles with enacted limits on DEHP content (*e.g.,* children's toys and childcare items), it was considered reasonable that consumers might be exposed to older items with DEHP content higher than current limits via secondhand purchases or long-term use. For such items, exposures from new and legacy items were considered separately.

In addition to DEHP weight fractions, EPA obtained additional information about physical characteristics and potential uses of specific products and articles from technical specifications, manufacturer websites, and vendor websites. These data were used in the assessment needed to define

exposure scenarios. The following sections provide a summary of specific products and articles with DEHP content identified for each item; Table 2-2 provides a summary of TSCA COUs determined for each item and exposure pathway modeled.

2.1.1 Solid Articles

Although DEHP is known to be used in a large variety of solid articles, weight fraction data for solid articles sold in the United States were limited. The majority of U.S. data were taken from a Washington State Department of Ecology (WSDE) study on phthalates in children's products and packaging materials (WSDE, 2020). Thats study included data for DEHP content in clothing and accessory items, toys, holiday/seasonal items, personal care products, packaging materials, and a variety of other small items purchased from retailers during the spring of 2012 (see Table 2 of that study). Measurement data were obtained from the WSDE Consumer Product Monitoring Database and filtered to remove measurements below the limit of detection and/or with low confidence (*i.e.*, reported as an estimate) before sorting into groups of like items for modeling. Only relevant non-personal care products and articles were considered for this TSCA DEHP exposure assessment. Data for personal care products was not included as it is outside the scope of this assessment and because they are regulated under the Federal Food, Drug, and Cosmetic Act (FFDCA) and excluded from the definition of a chemical substance under TSCA (per Section 3(2)(B)).

While data for DEHP content in toys and other children's items from studies conducted in Europe and Canada were identified, the information was not used in this assessment as the data from the Washington State database was considered adequate to characterize exposure. As data for DEHP content in solid items not specific to children were lacking for U.S. consumer goods, a significant amount of data was taken from monitoring campaigns of phthalates in consumer goods conducted in European countries, and these values are assumed to be similar to contents in comparable items sold in the United States. In particular, a large amount of data was available for phthalates in consumer goods published across several studies conducted by the Danish EPA. A full description of data sources for DEHP content in solid articles modeled for consumer exposure in this assessment is provided below.

Given the high molecular weight (390.56 g/mol) and low vapor pressure (1.42×10^{-7} mmHg) of DEHP, partitioning into air and overlying dust from solid articles is expected to be limited. Consequently, inhalation and dust ingestion exposure for items with small surface area of emissions (<1 m^2) or those used outdoors are expected to be insignificant as compared to exposure by mouthing and dermal contact. As such, inhalation and dust ingestion were not assessed for these items. Note that for solid articles assessed only for mouthing and/or dermal contact, DEHP content is provided herein for context only as it is not used directly in exposure calculations for these routes.

Adult Toys

Adult toys, also known as intimacy and sex toys, are objects that people use to increase or facilitate sexual pleasure. Examples of adult toys include vibrators and dildos. These articles were assessed for DEHP exposure by mouthing and dermal routes. Vaginal and anal exposures, labeled as adult toy mucosal membrane exposures, were not quantitatively assessed due to a lack of use pattern information and modeling tools to calculate exposure for articles with vaginal and anal use. DEHP content was reported at 0.00002 w/w (weight per weight) in an adult toy sample purchased in the United States (Sipe et al., 2023). Additionally, DEHP was reported by the Danish EPA in eight adult toy items at weight fractions ranging from 0.00073 to 0.702 w/w. (Nilsson et al., 2006). Based on these data, weight fraction values of 0.00002, 0.26, and 0.7 w/w were applied in low-, medium-, and high-exposure scenarios.

Air Beds
Air beds were assessed for DEHP exposure by inhalation, dust ingestion, and dermal pathways. Measurable DEHP was reported by the Danish EPA in 1 sleeping mat at 0.14 w/w (Danish EPA, 2012) and 13 air beds at weight fractions ranging from 0.00003 to 0.304 w/w (DTI, 2010). The air beds data distribution had three data points on the higher end of the range, 0.192, 0.238, and 0.304 w/w with the remaining seven data points were below 0.00022. This grouping at the higher- and lower-end of the distribution (bimodal distribution) shows a wide range of concentrations in air beds that may contribute to a wide range of exposure doses and risk estimates. Based on these data, weight fraction values of 0.00003, 0.11, and 0.304 w/w were applied in low-, medium-. and high-exposure scenarios, respectively.

Batteries
EPA identified battery products listing California Proposition 65 warnings for DEHP content, including battery replacements for trail cameras and digital camera batteries (Kastar, 2024; SPYPOINT, 2024; Thumper, 2024). Although it is not clear how DEHP is incorporated into batteries, this limitation does not impede EPA's exposure analysis for the following reasons. If DEHP is in battery components in the battery interior (*e.g.*, polymer electrolytes), there is little possibility of consumer exposure via inhalation, ingestion, or dermal routes. If DEHP is in the exterior of the battery, inhalation and ingestion exposures are expected to be negligible due to the small surface area of batteries and because batteries are commonly encased and not exposed to indoor dust. Dermal exposures to DEHP used on the battery exterior would be evaluated with the PVC articles with potential for semi-routine dermal exposure.

Car Mats
Car floor mats were assessed for DEHP exposure by inhalation, dust ingestion, and dermal pathways. Numerous instances of commercially available car floor mats containing DEHP were found but none disclosed specific chemical contents. The only available data for DEHP content in car mats were two car mat sets purchased from an internet vendor in Denmark, with reported weight fractions of 0.087 and 0.128 w/w DEHP (Danish EPA, 2020). As data specific to the U.S. market is lacking, these values will be used in low and high exposure scenarios. The average value, 0.108 w/w, was used in the medium-exposure scenario.

Children's Toys
Children's toys (*i.e.*, articles intended for children to play with) were assessed for DEHP exposure by inhalation, dust ingestion, dermal, and mouthing routes of exposure. Under the CPSIA of 2008, Congress permanently prohibited the sale of children's toys or child-care articles containing concentrations of more than 0.1 percent of certain phthalates. However, it is possible that some individuals may still have children's toys in the home that were produced before statutory and regulatory limitations established by CPSIA section 108(a) and 16 CFR 1307.3(a). DEHP reporting in Washington State database dates from 2017 to 2024. Among the data for children's items from the Washington State database (WSDE, 2020), a total of 19 toy items had measurable DEHP content. Among all 19 items, the minimum, average, and maximum weight fractions reported were 8.3×10^{-6}, 0.023, and 0.33 w/w. respectively.

EPA assessed exposure to DEHP in children's toys under two scenarios. In the first exposure scenario, new toys produced for the U.S. market are assumed to comply with statutory and regulatory limits and were assessed with DEHP weight fractions of 0.1 percent in low-, medium-, and high-exposure scenarios. In the second scenario, legacy toys are assessed with weight fractions reported in the Washington State database. The minimum, average, and maximum weight fractions provided above were used in low-, medium-, and high-exposure scenarios. Five new toys in the Washington State database tested 8 or more years after the CPSIA had components with DEHP content above the statutory

and regulatory limit of 0.1 percent (WSDE, 2020). The legacy toys scenario is more representative of any new toys with weight fractions above the CPSIA statutory and regulatory limit.

Clothing

Clothing was assessed for DEHP exposure by dermal contact only, but a different approach was taken for adults and children based on anticipated contact with specific garments. DEHP content was reported in two adult-sized garments by the Danish EPA. This included DEHP reported at 0.117 w/w in the outer layer of a raincoat (Danish EPA, 2020) and 0.00037 w/w in a pair of mittens. However, DEHP has also been reported in synthetic leather materials sampled from furniture items (see coated textiles description below). It is reasonable to assume that these materials may be used in synthetic leather clothing as well, which are expected to have a greater potential for dermal exposure as it may be worn more often than raincoats and mittens, has direct dermal contact, and may have a larger area of dermal contact. As a conservative assumption, synthetic leather clothing exposure scenarios are represented by the high- to low-intensity use scenarios, while raincoats and mittens are better represented by the medium- and low-intensity use scenarios. The synthetic leather scenario was only assessed for dermal exposure to DEHP in adults and teens. The weight fractions used in modeling correspond to 2×10^{-5} w/w, 0.12 w/w, and 0.34 w/w for low-, medium-, and high-intensity use exposure scenarios (see coated textiles section).

The Washington State database reported measurable DEHP content for one child's garment; the outer fabric of a child's jacket was reported to contain 7.4×10^{-6} w/w DEHP (WSDE, 2020). Given the very low concentration of DEHP and limited dermal contact arising from its use on the outside layer of clothing, DEHP exposure from this or similar jacket items is not expected to be significant. In addition, infants and children are not anticipated to wear synthetic leather clothing. As such, dermal exposure to DEHP from clothing was not modeled explicitly for infants and children; however, the potential for dermal contact with these items is captured under the scenario "small items with the potential for significant aggregated contact" outlined below.

Coated Textiles

Coated textiles were assessed for DEHP exposure via inhalation, ingestion, mouthing, and dermal uptake. The Danish EPA reported DEHP measurements for both synthetic leather and oil cloth fabrics (DTI, 2010). Synthetic leather samples were taken from furniture items and reported DEHP contents ranged from 2×10^{-5} to 0.392 w/w. Oil cloth samples had reported DEHP contents ranging from 3×10^{-5} to 0.253 w/w. Oil cloth material is not incorporated extensively in household items or clothing but may be used to manufacture tablecloths. Synthetic leather is expected to have many potential applications, including furniture, clothing, and accessory items such as belts and handbags. Exposure to coated textiles will be assessed as two representative articles expected to capture the highest exposure by inhalation, dermal uptake, and ingestion due to large surface area of emissions and long dermal contact times. To that end, consumer exposure to DEHP from coated textiles was modeled in scenarios for furniture and clothing. As oil cloth has lower reported weight fractions of DEHP and is expected to occur in smaller surface area items than furniture, exposure from these materials is expected to be less than that of synthetic leather furniture. As such, low-, medium-, and high-exposure scenarios used the minimum, average, and maximum reported DEHP weight fractions of 2.0×10^{-5}, 0.12, and 0.34 w/w in synthetic leather. respectively.

Erasers

Pencil and chalk erasers were assessed for DEHP exposure by the mouthing exposure route. A study by the Danish EPA found measurable concentrations of DEHP in four erasers with weight fractions ranging from 0.17 to 0.44 w/w (Svendsen et al., 2007). No recent data were available with DEHP measurements in eraser products sold in the United States, but it is unclear if this is because DEHP is not present in

U.S.-sold erasers or they were not captured in monitoring efforts. However, given the lack of regulations for DEHP content in these products, EPA assessed exposure to DEHP through mouthing of erasers under the assumption that significant contents could be present in some products.

Footwear

Footwear components were assessed for DEHP exposure by dermal contact only. DEHP content was reported by the Danish EPA in several items, including flip flops with 0.032 w/w (Danish EPA, 2020) and two rubber clog samples with DEHP contents of 0.0008 and 0.05 w/w (Danish EPA, 2009). DEHP content in footwear components was also reported in the Washington State Database at weight fractions ranging from 1.77×10^{-5} to 0.0063 w/w. However, in many instances these measurements were for small components on the exterior of the item and therefore not expected to be a significant source of exposure. Three measurements were reported for footwear components with the potential for significant dermal contact (*i.e.*, insoles, shoe inserts, and soles). Weight fractions of DEHP reported for these items were generally quite low, ranging from 7.4×10^{-6} to 3.3×10^{-5} w/w.

Mobile Phone Covers

Mobile phone covers were assessed for DEHP exposure by dermal contact only. DEHP content was reported in five mobile phone covers by the Danish EPA with weight fractions ranging from 0.0012 to 0.13 w/w. No data were available with DEHP measurements in U.S.-sold phone covers, but it is unclear if this is because DEHP is not present in U.S.-sold phone covers or they were not captured in monitoring efforts. As such, EPA assessed these products under the assumption that significant DEHP content could be present in some products.

PVC Articles with Potential for Semi-Routine Dermal Exposure

DEHP has been measured in a variety of consumer goods that are (1) not expected to be mouthed, (2) not expected to result in significant inhalation exposure due to their small size and/or outdoor only use, and (3) not expected to result in significant dermal exposures due to short and/or infrequent dermal contact events. However, EPA recognizes that while dermal uptake of DEHP from contact with these individual items is not expected to be significant, given the widespread nature of the items, an individual could have significant daily contact with some combination of these items and/or with other similar items that have not been measured during monitoring campaigns. As such, these items have been grouped together for modeling but represent a variety of COUs under TSCA. It is likely that real-world exposures to these types of items would occur as a result of dermal contact with articles belonging to multiple COUs. However, the contribution of individual COUs to exposure from these kinds of items is expected to vary at an individual level due to differences in lifestyle and habits. As such, though this scenario encompasses items from many COUs, it may be viewed as an upper boundary for exposure to any of the COUs included. A full list of items included in this scenario is shown in Table 2-1. Because weight fractions of DEHP are not used in dermal exposure calculations, they are provided here only to demonstrate the broad range of articles and DEHP contents that may be captured in this model scenario.

Table 2-1. Items Modeled Under the "Articles with the Potential for Semi-Routine Dermal Exposure" Scenario

Condition of Use	Source	Item	DEHP Weight Fraction (w/w)		
			Low	Med.	High
Arts, crafts, and hobby materials	(WSDE, 2020)	Arts and crafts supplies (pencils and pencil pouches)	0.00002	0.002	0.009
	(Danish EPA, 2020)	Hobby cutting board	0.013	0.0155	0.018
	(Ecology Center, 2015)	Pencil pouch	0.003	0.068	0.137

Condition of Use	Source	Item	DEHP Weight Fraction (w/w)		
			Low	Med.	High
Electrical and electronic products	(Danish EPA, 2020)	Phone charger	0.005		
	(Ecology Center, 2015)	Wireless earbuds	0.114		
	(3M, 2011)	3M™ economy vinyl electrical tape 1400, 1400C	0.07	0.085	0.1
Fabric, textile, and leather products not covered elsewhere	(WSDE, 2020)	Bags and wallets (children's)	0.00001	0.013	0.036
	(WSDE, 2020)	Footwear interior components (children's)	0.000007	0.00018	0.00003
	(WSDE, 2020)	Children's jacket (exterior fabric)	0.000007		
	(Danish EPA, 2012)	Handbags	0.0007	0.04035	0.08
Lawn and garden care products	(Danish EPA, 2020)	Garden hose	0.061		
	(Ecology Center, 2016)	Garden hose	0.013	0.02	0.026
Plastic and rubber products not covered elsewhere	(WSDE, 2020)	Vinyl bags and baskets (household use)	0.000053	0.00009	0.0001
	(WSDE, 2020)	Holiday items	0.000016	0.024	0.19
	(WSDE, 2020)	Miscellaneous items (toilet stickers, vinyl covers for journals and planners, paint roller)	0.00002	0.054	0.16
	(WSDE, 2020)	Light up jewelry (children's)	0.000024	0.00071	0.0014
	(WSDE, 2020)	Packaging	0.00001	0.03	0.20
	(Danish EPA, 2020)	Pet chew toy	0.17	0.22	0.28
	(Danish EPA, 2020)	Feeding mat	0.061	0.099	0.14
	(Danish EPA, 2009)	Soap packaging	0.00013	0.036	0.08
	(Tsumura et al., 2001)	PVC gloves	0.075	0.25	0.41
	(Danish EPA, 2020)	PVC gloves	0.38		
	(Danish EPA, 2012)	Work gloves	0.26		
	(Danish EPA, 2020)	Household bags	0.00005	0.00053	0.001
	(Danish EPA, 2020)	Outdoor furniture cover		0.047	
	(Ecology Center, 2015)	Tub mat	0.00163		
	(Ecology Center, 2015)	Bathtub appliques	0.069		
	(Danish EPA, 2009)	Bathmats	0.129		
	(DTI, 2010)	Lampshade	0.00001	0.00010	0.00037
	(Ecology Center, 2015)	Vinyl floor runner	0.028829	0.028829	0.028829
	(DTI, 2010)	Dinner mat	0.000010		
	(Ecology Center, 2015)	Car steering wheel cover	0.17		
	(Danish EPA, 2020)	Diving goggles	0.069		
	(Ecology Center, 2015)	Silly straws	0.015		
	(Danish EPA, 2020)	Wall sticker		0.12	
Toys, playground, and sporting equipment	(DTI, 2010)	Fitness balls	0.0000090	0.13	0.44
	(Danish EPA, 2020)	Jump rope	0.084	0.13	0.17
	(Danish EPA, 2020)	Yoga mat	0.0000060		
	(Danish EPA, 2020)	Football	0.0000070	0.11	0.22

Tire Crumb Rubber

Tire crumb rubber was assessed for DEHP exposure by inhalation, ingestion, and dermal pathways. DEHP content was reported in tire crumb sampled from both outdoor (n = 25) and indoor playing fields

(n = 15).

Shower Curtains
Shower curtains were assessed for DEHP exposure by inhalation, dust ingestion, and dermal exposure routes. DEHP weight fractions in PVC shower curtains were reported for five shower curtains purchased from major U.S. retailers (Camann et al., 2008). Of the five curtains tested, all had measurable DEHP content ranging from 0.0014 to 0.48 w/w. DEHP was also reported by the Danish EPA in eight shower curtains with weight fractions ranging from 0.0005 to 0.282 w/w (DTI, 2010). Based on the data reported in these studies, the weight fraction values used in low-, medium-, and high-exposure scenarios for PVC shower curtains were 0.0005, 0.18, and 0.48 w/w, respectively.

Vinyl Flooring
Vinyl flooring was assessed for DEHP exposure by inhalation, dust ingestion, and dermal exposure routes. The Danish EPA reported DEHP in two vinyl flooring materials at 0.003 and 4.9×10^{-5} w/w (DTI, 2010). In addition, DEHP content was reported at 0.028 w/w for one vinyl flooring sample obtained from a U.S. retailer (Ecology Center, 2015). Based on the data reported in these studies, the weight fraction values used in low-, medium-, and high-exposure scenarios for vinyl flooring were 4.9×10^{-5}, 0.014, and 0.028 w/w, respectively.

Wallpaper
Wallpaper was assessed for DEHP exposure by inhalation, dust ingestion, and dermal exposure routes. DEHP was reported by the Danish EPA for six wallpaper samples (DTI, 2010). The minimum, mean, and maximum weight fractions of DEHP reported were 1×10^{-5}, 2.5×10^{-5}, and 4×10^{-5} w/w; these values were used in the low-, medium-, and high-exposure scenarios. No data were found with DEHP measurements in U.S.-sold wallpaper, but it is unclear if this is because DEHP is not present in U.S.-sold wallpaper or these materials have not been captured in monitoring efforts. As such, EPA assessed these products under the assumption that the weight fractions reported by the Danish EPA are representative of DEHP content that could be present in wallpaper sold in the United States.

Wire Insulation
Wire insulation was assessed for DEHP exposure by inhalation, dust ingestion, dermal, and mouthing (primarily of concern for children <5 years) exposure routes. Mouthing of cables and wires for children under 5 years was assessed as an incidental or unintentional exposure based on behavioral patterns expected for these lifestages. DEHP content was reported by the Ecology Center Nonprofit Group at 0.14 w/w for a single insulated cord purchased in the United States (Ecology Center, 2015). This value was applied in low-, medium-, and high-exposure scenarios.

2.1.2 Liquid and Paste Products

Liquid and paste products with DEHP content were identified by manufacturer safety data sheets (MSDSs). Products with similar DEHP content and expected use patterns were grouped together for modeling as described below. Note that for liquid and paste products assessed only for dermal exposure, DEHP content is provided here for context only as it is not used directly in exposure calculations for these routes.

Adhesives and Sealants for Home DIY Projects
One sealant with DEHP was identified for sealing concrete after installation of inductance loops (*e.g.*, use in driveway pressure sensors for security systems). The reported DEHP content was 2.5 to 10 percent (Royal Adhesives & Sealants, 2019). Because the anticipated use for this product was outdoors and product use is not expected to generate aerosols, inhalation exposure is expected to be negligible;

therefore, this product was modeled for dermal exposure only.

Three weatherproofing concrete sealers were identified with DEHP content of 0.1 to 0.2 percent (Clemons Concrete Coatings, 2018), 0.1 to 0.2 percent (Eagle, 2015a), and 0.15 percent (Eagle, 2015c). Additionally, one colorant used to tint cement sealants was identified with DEHP content ranging from 0.1 to 1 percent (Tremco Canadian Sealants, 2015). Given the low DEHP content and anticipated outdoor only use, inhalation exposure is expected to be negligible, and these products were modeled for dermal exposure only.

One adhesive for hardwood and laminate floor installation was identified with DEHP content in the range of 15 to 30 percent (DeLima Associates, 2015). Based on these data the weight fractions of DEHP used in low-, medium-, and high-exposure scenarios for this product were 0.15, 0.225, and 0.3 w/w, respectively. This product was assessed for both inhalation and dermal exposure.

Automotive Adhesives and Sealants

Two adhesive/sealant products for automotive applications were identified with DEHP content. Reported DEHP contents were 1 to 5 percent (Quest Automotive Products, 2015) and 3 to 5 percent (Valspar, 2024). Based on these data, the DEHP weight fractions used in low-, medium-, and high-exposure scenarios for these products were 0.01, 0.03, and 0.05 w/w, respectively. These products were assessed for dermal exposure. Inhalation exposure is not expected to be significant for these products as they are typically used in very small quantities and are not applied in a manner that will generate aerosols.

Automotive Coatings

Two primer and coating products for automotive applications were identified with DEHP content. Reported DEHP contents were 1 to 5 percent (3M, 2017) and 0.3 percent (Dupli-Color Products Company, 2017). Based on these data, the DEHP weight fractions used in low-, medium-, and high-exposure scenarios for these products were 0.003, 0.01, and 0.05 w/w. These products were assessed for both inhalation and dermal exposure.

Stamp Ink

One stamp product, including liquid ink refills, was identified with DEHP content. The reported DEHP content was 0.2 percent (Identity Group, 2016b); this weight fraction was used in low-, medium-, and high-exposure scenarios for this product. This product was assessed for dermal exposure only. However, the product is intended for use in the manufacturing of pre-inked handstamps for the purpose of marking or printing on porous substrates such as paper or paper board. Therefore, there is no direct exposure during typical use of these products.

Table 2-2 provides a summary of TSCA COUs determined for each item and exposure pathways modeled. Note that small articles with potential for semi-routine contact results are presented as multiple COU categories and a subcategory.

Table 2-2. Summary of Consumer COUs, Exposure Scenarios, and Exposure Routes

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
						Ingestion		
				Inhalation [a]	Dermal	Suspended Dust	Settled Dust	Mouthing
Automotive, fuel, agriculture, outdoor use products	Lawn and garden care products	Small articles with the potential for semi-routine contact: hose	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Adhesives and sealants	Adhesive/sealant for home DIY, large indoors	Use of product in DIY large-scale home repair activities; direct contact during use; inhalation of emissions during use	**QT**	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Adhesives and sealants	Adhesive/sealant for home DIY, small outdoors	Direct contact during application	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Adhesives and sealants	Automotive filler/putty	Use of product in DIY small-scale auto repair. Direct contact during use; inhalation of emissions	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Batteries	Batteries	Contact is expected to be infrequent	**QT**	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Vinyl flooring	Direct contact, inhalation of emissions / ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Wallpaper	Two scenarios, installation, and in-place. Direct contact during installation (teenagers and adults) and while in place; inhalation of emissions / ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Construction, paint, electrical, and metal products	Machinery, mechanical appliances, electrical/ electronic articles	Small articles with the potential for semi-routine contact: phone charge, wireless earbuds, electrical tape	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Machinery, mechanical appliances, electrical/	Insulated cords	Direct contact, inhalation of emissions/ ingestion of dust adsorbed	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
						Ingestion		
				Inhalation [a]	Dermal	Suspended Dust	Settled Dust	Mouthing
	electronic articles		chemical, mouthing by children					
Construction, paint, electrical, and metal products	Paints and coatings	Coating for home DIY, large outdoors	Direct contact during application.	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Paints and coatings	Automotive coating	Use of product in DIY small-scale auto repair; direct contact during use; inhalation of emissions	**QT**	**QT**	*QL*	*QL*	*QL*
Furnishing, cleaning, treatment care products	Fabric, textile, and leather products; furniture and furnishings	Synthetic leather furniture	Direct contact during use; inhalation of emissions / ingestion of airborne particulate; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Furnishing, cleaning, treatment care products	Fabric, textile, and leather products; furniture and furnishings	Synthetic leather clothing	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Furnishing, cleaning, treatment care products	Fabric, textile, and leather products; furniture and furnishings	Small articles with the potential for semi-routine contact: outdoor furniture, children's bags, wallets, footwear, interior and exterior components of jackets, handbags	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Furnishing, cleaning, treatment care products	Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles; fabrics, textiles, and apparel	Vinyl flooring	Direct contact, inhalation of emissions/ ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Furnishing, cleaning, treatment care products	Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles; fabrics, textiles, and apparel	Wallpaper	Two scenarios, installation, and in-place; direct contact during installation (teenagers and adults) and while in place; inhalation of emissions/ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Packaging, paper, plastic, toys, hobby products	Ink, toner, and colorants	Stamp ink	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
				Inhalation [a]	Dermal	Ingestion		
						Suspended Dust	Settled Dust	Mouthing
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Air mattresses and sleeping mats	Direct contact during use; inhalation of emissions/ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Rubber eraser	Direct contact during use; rubber particles may be inadvertently ingested during use. Eraser may be mouthed by children	*QL*	**QT**	*QL*	*QL*	**QT**
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Mobile phone covers	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Shower curtain	Direct contact during use; see routine contact scenario inhalation of emissions / ingestion of dust adsorbed chemical while hanging in place	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Small articles with the potential for semi-routine contact: packaging, paper, plastic, toys, hobby products: cutting board, pencils, pouches, bags, hose, labels, covers, chewy toys, jewelry, gloves, packaging, mats,	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
				Inhalation [a]	Dermal	Ingestion		
						Suspended Dust	Settled Dust	Mouthing
		lampshade, vinyl floor runner, diving goggles, silly straws, stickers, diving goggles						
Packaging, paper, plastic, toys, hobby products	Packaging (excluding food packaging), including paper articles	Small articles with the potential for semi-routine contact: Packaging, paper, hobby products: pencils, labels, covers, lampshade, stickers	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Packaging, paper, plastic, toys, hobby products	Toys, playground, and sporting equipment	Children's Toys (legacy)	Collection of toys; direct contact during use; inhalation of emissions/ingestion of airborne particulate; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Packaging, paper, plastic, toys, hobby products	Toys, playground, and sporting equipment	Children's Toys (new)	Collection of toys; direct contact during use; inhalation of emissions/ ingestion of airborne PM; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Packaging, paper, plastic, toys, hobby products	Toys, playground, and sporting equipment	Tire crumb, artificial turf	Direct contact during use (particle ingestion via hand-to-mouth)	**QT**	**QT**	**QT** [c]		
Packaging, paper, plastic, toys, hobby products	Toys, playground, and sporting equipment	Small articles with the potential for semi-routine contact: Fitness balls, jump rope, yoga mat, football, and diving goggles	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Other	Novelty articles	Adult toys	Direct contact during use, ingestion by mouthing	*QL*	**QT**	*QL*	*QL*	**QT**
Other	Automotive articles	Car mats	Direct contact during use; see routine contact scenario inhalation of emissions/ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
						Ingestion		
				Inhalation [a]	Dermal	Suspended Dust	Settled Dust	Mouthing
Other	Automotive articles	Tire replacement	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Disposal	Disposal	Down the drain products and articles	Down the drain and releases to environmental media	*QL*	*QL*	*QL*	*QL*	*QL*
Disposal	Disposal	Residential end-of-life disposal, product demolition for disposal	Product and article end-of-life disposal and product demolition for disposal	*QL*	*QL*	*QL*	*QL*	*QL*

DIY= do-it-yourself; *QL* = qualitative consideration; **QT** = quantitative consideration

[a] Inhalation scenarios consider suspended dust and gas-phase emissions.

[b] Scenario used in Indoor Dust Exposure Assessment in Section 4. These indoor dust articles scenarios consider the surface area from multiple articles such as toys, while furniture and flooring already have large surface areas. For these articles dust can deposit and contribute to significantly larger concentration of dust than single small articles.

[c] The tire crumb and artificial turf ingestion route assessment considers all three types of ingestions, settled dust, suspended dust, and mouthing altogether, but results cannot be provided separately as it was done for all other articles and products.

Disposal consideration; see Section 2 of the *Consumer and Indoor Dust Exposure Assessment for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025a) for qualitative assessments (*i.e.*, batteries, stamp ink, and disposal qualitative assessments) for a detailed qualitative discussion of disposal exposures. Note that exposures resulting from disposing of down the drain are primarily expected to affect the environmental organisms and the general population who are downstream from wastewater releases. However, exposures from disposal in general could not be estimated due to key uncertainties discussed in Section 2 of the *Consumer and Indoor Dust Exposure Assessment for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025a).

Qualitative Assessment
EPA did not perform quantitative assessments of the COU summarized in Table 2-3 due to lack of reasonably available information, monitoring data, and modeling tools. Instead, EPA provided a qualitative discussion below using physical and chemical properties and monitoring data for environmental media to support conclusions about down the drain and disposal practices and releases to the environment.

Table 2-3. COUs and Products or Articles Without a Quantitative Assessment

Consumer Use Category	Consumer Use Subcategory	Product/Article	Comment
Disposal	Disposal	Down the drain products and articles	Qualitative assessment – due to limited information on source attribution of the consumer COUs

Environmental releases may occur from consumer products and articles containing DEHP via the end-of-life disposal and demolition of consumer products and articles in the built environment, as well as from the associated down-the-drain release of DEHP. It is difficult for EPA to quantify these end-of-life and down-the-drain exposures due to limited information on source attribution of the consumer COUs. In previous assessments, the Agency has considered down-the-drain analysis for consumer product scenarios where it can be reasonably foreseen that the consumer product (*e.g.*, paints, sealants, oils) will be discarded directly down-the-drain. Although EPA acknowledges that there may be DEHP releases to the environment via the cleaning and disposal of adhesives, sealants, paints, lacquers, and coatings, the Agency did not quantitatively assess these scenarios due to limited information, monitoring data, or modeling tools. Adhesives, sealants, paints, lacquers, and coatings can be disposed down-the-drain while users wash their hands, brushes, sponges, and other product applying tools. In addition, these products can be disposed when they are no longer used or they have reached the product shelf life and are taken to landfills. All other solid products and articles in Table 2-2 can be removed and disposed in landfills or other waste handling locations that properly manage the disposal of products like adhesives, sealants, paints, lacquers, and coatings.

EPA identified two sources that reported DEHP concentrations in U.S. drinking water [see Section 6.2 in U.S. EPA (2025f)]. In summary, the available monitoring data in the U.S. for finished drinking water, DEHP was only detectable in 0.45 percent of samples, corroborating the expectation of high treatment removal efficiencies. Based on the low water solubility and log K_{OW}, DEHP in water is expected to mainly partition to suspended solids present in water. The available information suggest that the use of flocculants and filtering media could potentially help remove DEHP during drinking water treatment by sorption into suspended organic matter, settling, and physical removal. Although there is limited measured data on DEHP in landfill leachates, the data suggest that DEHP is unlikely to be present in landfill leachates. Furthermore, the small amounts of DEHP that could potentially be in landfill leachates will have limited mobility and are unlikely to infiltrate groundwater due to high affinity of DEHP for organic compounds that would be present in receiving soil and sediment (U.S. EPA, 2025f).

2.2 Inhalation and Ingestion Modeling Approach

CEM Version 3.2 (U.S. EPA, 2023) was selected for the consumer exposure modeling as the most appropriate model to use based on the type of input data available for DEHP-containing consumer products. The advantages of using CEM to assess exposures to consumers and bystanders are as follows:

- CEM model has been peer reviewed (ERG, 2016);

- CEM accommodates the distinct inputs available for the products and articles containing DEHP, such as weight fractions, product density, room of use, frequency and duration of use, see Section 2.3.3 for specific product and article scenario inputs; and
- CEM uses the same calculation engine to compute indoor air concentrations from a source as the higher-tier Multi-Chamber Concentration and Exposure Model (MCCEM) but does not require measured chamber emission values (which are not available for DEHP).

CEM has capabilities to model exposure to DEHP from both products and articles containing the chemical. Products are generally consumable liquids, aerosols, or semi-solids that are used a given number of times before they are exhausted. Articles are generally solids, polymers, foams, metals, or woods, which are present within indoor environments for the duration of their useful life, which may span several years.

CEM 3.2 generates exposure estimates based on user-provided input parameters and various assumptions (or defaults). The model contains a variety of pre-populated scenarios for specific product, and article categories and allows the user to define generic categories for any product or article where the prepopulated scenarios are not adequate. User inputs for physical and chemical properties of products, and articles are utilized to calculate emission profiles of semi-volatile organic compounds (SVOCs). There are six emission calculation profiles within CEM (E1–E6) that represent specific use conditions and properties of various products and articles. A description of these models is summarized in the CEM user guide and associated appendices (accessed November 25, 2025).

CEM Version 3.2 estimates acute dose rates and chronic average daily doses for inhalation, ingestion, and dermal exposures of consumer products and articles. However, for the purpose of this assessment, EPA performed dermal calculations outside of CEM; see Section 2.3 for approach description and input parameters. CEM 3.2 acute exposures are for an exposure duration of 1 day while chronic exposures are for an exposure duration of 1 year. The model provides exposure estimates for various lifestages. EPA made some adjustments to match CEM's lifestages to those listed in the U.S. Centers for Disease Control and Prevention (CDC) guidelines (CDC, 2021) and EPA's *A Framework for Assessing Health Risks of Exposures to Children* (U.S. EPA, 2006). CEM lifestages are re-labeled from this point forward as follows:

- Adult (21+ years) → Adults
- Youth 2 (16–20 years) → Teenagers and young adults
- Youth 1 (11–15 years) → Young teens
- Child 2 (6–10 years) → Middle childhood
- Child 1 (3–5 years) → Preschoolers
- Infant 2 (1–2 years) → Toddlers
- Infant 1 (<1 year) → Infants

Exposure inputs for these various lifestages are provided in the EPA's CEM Version 3.2 Appendices.

2.2.1 Inhalation and Ingestion Modeling for Products

The calculated emission rates are then used in a deterministic, mass balance calculation of indoor air concentrations. However, CEM employs different models for products and articles. For products, CEM 3.2 uses a two-zone representation of the building of use when predicting indoor air concentrations. Zone 1 represents the room where the consumer product is used. Zone 2 represents the remainder of the building. Each zone is considered well-mixed. The model allows for further division of Zone 1 into a near-field and far-field to accommodate situations where a higher concentration of product is expected very near the product user during the period of use. Zone 1 near-field represents the breathing zone of

the user at the location of the product use, while Zone 1 far-field represents the remainder of the Zone 1 room. The modeled concentrations in the two zones are a function of the time-varying emission rate in Zone 1, the volumes of Zones 1 and 2, the air flows between each zone and outdoor air, as well as the air flows between the two zones. Following product use, the user and bystander may follow one of three predefined activity patterns: full-time worker, part time worker, and stay-at-home. The activity use pattern determines which Zone is relevant for the user and bystander and the duration of the exposures. The user and bystander inhale airborne concentrations within these zones, which can vary over time, resulting in the overall estimated exposure for each individual. The stay-at-home activity pattern was selected for this assessment for all scenarios as the most conservative behavior pattern for a screening approach, with the option for further refinement should risk be identified in the screening level analysis. For the "Stay-at-Home" activity pattern used in these analyses, both users and bystanders are assumed to be in the home for the majority of the day (20 hours).

CEM default air exchange rates for the building are from the *Exposure Factors Handbook* (also called the "Handbook") (U.S. EPA, 2011c). The default interzonal air flows are a function of the overall air exchange and volume of the building as well as the openness of the room, which is characterized in a regression approach for closed rooms and open rooms (U.S. EPA, 2023) (see Section 2.3.3 for product scenario specific selections of environment such as living room vs. whole house, or indoor vs. outdoor and the air exchange rate used per environment selection). Kitchens, living rooms, and the garage area are considered more open, with an interzonal ventilation rate of 109 m^3/h. Bedrooms, bathrooms, laundry rooms, and utility rooms are considered less open, and an interzonal ventilation rate of 107 m^3/h is applied. In instances where the whole house is selected as the room of use, the entire building is considered Zone 1, and the interzonal ventilation rate is therefore equal to the negligible value of 1×10^{-30} m^3/hour. In instances where a product might be used in several rooms of the house, air exchange rate was considered in the room of use to ensure that effects of ventilation were captured.

2.2.2 Inhalation and Ingestion Modeling for Articles

For articles, the model comprises an air compartment (including gas-phase, suspended particulates) and a floor compartment (containing settled particulates). SVOCs emitted from articles partition between indoor air, airborne particles, settled dust, and indoor sinks over time. Multiple articles can be incorporated into one room over time by increasing the total exposed surface area of articles present within a room. CEM 3.2 models exposure to SVOCs emitted from articles via inhalation of airborne gas- and particle-phase SVOCs, ingestion of previously inhaled particles, dust ingestion via hand-to-mouth contact, and ingestion exposure via mouthing. Abraded particles are first emitted to the air and thereafter may deposit and resuspend from the surfaces. Abraded particles, similar to suspended and settled particulates, are subject to cleaning and ventilation losses. As such, abraded particles, both in the suspended and settled phases, are not assumed to be in equilibrium with the air phase. Thus, the chemical transfer between particulates and the air phase is kinetically modeled in terms of two-phase mass transfer theory. In addition, abraded particles settled on surfaces are assumed to have a hemispherical area available for emission, whereas those suspended in the air have a spherical area available for emission.

In inhalation scenarios where DEHP is released from an article into the gas-phase, the article inhalation scenario tracks chemical transport between the source, air, airborne and settled particles, and indoor sinks by accounting for emissions, mixing within the gas-phase, transfer to particulates by partitioning, removal due to ventilation, removal due to cleaning of settled particulates and dust to which DEHP has partitioned, and sorption or desorption to/from interior surfaces. The emissions from the article were modeled with a single exponential decay model. This means that the chronic and acute exposure duration scenarios use the same emissions/air concentration data based on the weight fraction of the

chemical in the article but have different averaging times. The acute data uses concentrations for a 24-hour period at the peak of the simulated emissions, while the chronic data was averaged over the entire one-year period. Because air concentrations for most of the year are significantly lower than the peak value, the air concentration used in chronic dose calculations are usually lower than that used to calculate an acute dose.

2.2.3 CEM Modeling Inputs and Parameterization

The COUs that were evaluated for DEHP consisted of both products and articles. The embedded models within CEM 3.2 that were used for DEHP are listed in Table 2-4. As dermal exposure was modeled separately, only inhalation and ingestion routes were evaluated in CEM.

Table 2-4. CEM Version 3.2 Model Codes and Descriptions

Model Code	Description (in TSD)
E1	Emission from Product Applied to a Surface Indoors Incremental Source Model
E2	Emission from Product Applied to a Surface Indoors Double Exponential Model
E3	Emission from Product Sprayed
E6	Emission from Article Placed in Environment
A_INH1	*Inhalation from Article Placed in Environment*
A_ING1	*Ingestion after Inhalation*
A_ING2	*Ingestion of Article Mouthed*
A_ING3	*Incidental Ingestion of Dust*
P_INH2	*Inhalation of Product Used in an Environment*

Table 2-5 presents a crosswalk between the COU subcategories with either a predefined or generic scenario. Models were generated to reflect specific use conditions as well as physical and chemical properties of identified products, and articles. In some cases, one COU was mapped to multiple scenarios, and in other cases one scenario was mapped to multiple COUs. Table 2-5 provides data on emissions model and exposure pathways modeled for each exposure scenario. Emissions models were selected based upon physical and chemical properties of DEHP and application use method for products. Exposure pathways were selected to reflect the anticipated use of each product or article. The Article Model Ingestion of Article Mouthed (A_ING2) was only evaluated for the COUs where it was anticipated that mouthing of the product could occur. For example, it is unlikely that a child will mouth flooring or wallpaper, therefore the A_ING2 Model was deemed inappropriate for estimating exposure for these COUs. Similarly, solid articles with small surface area are not anticipated to contribute significantly to inhalation or ingestion of DEHP sorbed to dust/PM and were therefore not modeled for these routes (A_ING1, A_ING3). Note that products and articles not modeled for inhalation or ingestion exposure in CEM are not included in Table 2-6 below; these include auto repair putties, inductance loop sealants, clothing, mobile phone covers, tire crumb rubber, and small articles with potential for semi-routine contact.

Table 2-5. Crosswalk of COU Subcategories, CEM 3.2 Scenarios, and Relevant CEM 3.2 Models Used for Consumer Modeling

Consumer COU Category and Subcategory	Product/Article	Emission Model and Exposure Pathway Model(s)	CEM Default Exposure Scenarios
Automotive, fuel, agriculture, outdoor use products: Automotive products other than fluids	Car mats	E6, A_INH1, A_ING1, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Construction, paint, electrical, and metal products: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Wallpaper (in place)	E6, A_INH1, A_ING1, A_ING3	Fabrics: curtains, rugs, wall coverings
	Vinyl flooring	E6, A_INH1, A_ING1, A_ING3	Plastic articles: vinyl flooring
Construction, paint, electrical, and metal products: Adhesives and sealants including one-component caulk; fillers and putties	Flooring adhesive	E1, P_INH2 (near-field, users), P_INH1 (bystanders)	Glue and adhesives (large scale)
Construction, paint, electrical, and metal products: Electrical and electronic products (including as plasticizer)	Insulated cords	E6, A_INH1, A_ING1, A_ING2, A_ING3	Plastic articles: other objects with potential for routine contact (toys, foam blocks, tents)
Construction, paint, electrical, and metal products: Paints and coatings	Concrete sealant	E3, P_INH2 (near-field, users), P_INH1 (bystanders)	Generic P3 E3
	Automotive coating	E3, P_INH2 (near-field, users), P_INH1 (bystanders)	Generic P3 E3
Furnishing, cleaning, treatment care products: Fabric, textile, and leather products; furniture and furnishings	Synthetic leather furniture	E6, A_INH1, A_ING1, A_ING2, A_ING3	Leather furniture
Packaging, paper, plastic, toys, hobby products: Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including paper articles, rubber articles; plastic articles (hard); plastic articles (soft) (as plasticizer)	Air mattresses and sleeping mats	E6, A_INH1, A_ING1, A_ING3	Plastic articles: vinyl flooring
	Rubber eraser	No emissions modeled, A_ING2	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
	Shower curtain	E6, A_INH1, A_ING1, A_ING3	Plastic articles: other objects with potential for routine contact (toys, foam blocks, tents)
Packaging, paper, plastic, toys, hobby products: Toys, playground, and sporting equipment	Children's toys (legacy)	E6, A_INH1, A_ING1, A_ING2, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
	Children's toys (new)	E6, A_INH1, A_ING1, A_ING2, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Other: Novelty products	Adult toys	No emissions modeled, A_ING2	A_ING2; Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)

In total, the specific products representing 5 COUs categories and 15 subcategories for DEHP were mapped to 14 scenarios. Relevant consumer behavioral pattern data (*i.e.*, use patterns) and product-specific characteristics were applied to each of the scenarios and are summarized in Sections 2.2.3.1 and 2.2.3.2.

2.2.3.1 Key Parameters for Articles Modeled in CEM

Key input parameters for articles vary based on the exposure pathway modeled. For inhalation and dust

ingestion, higher concentrations of DEHP in air and dust will result in increased exposure. This may occur due to article specific characteristics that allow for higher emissions of DEHP to air and/or environment specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control DEHP emission rates from articles in CEM 3.2 models are weight fraction of DEHP in the material, density of article material (g/cm^3), article surface area (m^2), and surface layer thickness (cm); an increase in any of these parameters will result in increased emissions and greater exposure to DEHP. A detailed description of derivations of key parameter values used in CEM 3.2 models for articles is provided below, and a summary of values can be found in Table 2-6. Note that articles not modeled for inhalation exposure (*i.e.*, adult toys, clothing, erasers, mobile phone covers, and articles with semi routine dermal contact) are not included in Table 2-6.

Weight fractions of DEHP were calculated for each article. Material density was assumed to be a standard value for PVC of 1.4 g/cm^3 in all articles. Values for article surface layer thickness were taken from CEM default values for scenarios with emissions from the same or similar solid material. CEM default values for parameters used to characterize the environment (use volume, air exchange rate, and interzonal ventilation rate) were used for all models.

2.2.3.1.1 Surface Area

Due to the high variability and uncertainty inherent to article surface areas, low, medium, and high values were generally estimated for each item with the goal of capturing a reasonable range of values for this parameter. Assumptions for surface area estimates are outlined below.

2.2.3.1.2 Building Materials

To estimate surface areas for vinyl tile, it was assumed that the material was used in 100 percent, 50 percent, and 25 percent of the total floor space. The value for whole house floor space was calculated from the CEM house volume (492 m^3) and an assumed ceiling height of 8 feet, and the resulting values were applied in low-, medium-, and high-exposure scenarios.

The surface area of wallpaper in a residence was varied for the low-, medium-, and high-exposure scenarios. The medium value of 100 m^2 is based on Table 9-13 in the *Exposure Factors Handbook* (U.S. EPA, 2011c). This value was scaled to 200 and 50 m^2 for the high and low exposure scenarios, respectively, based on professional judgment.

2.2.3.1.3 Furniture

A furniture set consisting of a couch and loveseat was used as the representative article for textiles with DEHP content. To estimate the total surface area for a furniture set, an informal survey was conducted to identify common dimensions for these articles sold by various internet retailers. Based on this information, it was determined that there was considerable variability in sizes available, so small, medium, and large estimates were developed. The low, medium, and high surfaces areas, respectively, are based on open bottom (the bottom surface is not typically upholstered) prisms measuring 60” × 30” × 25”, 80” × 36” × 30”, and 100” × 42” × 35” for a couch and 48” × 30” × 25”, 60” × 36” × 30”, and 72” × 42” × 35” for a loveseat. The low exposure scenario is represented by the sum of the values of the low-end surface areas for a couch and a loveseat, and similarly for the medium and high estimates.

2.2.3.1.4 Air Beds

To identify the estimates for the surface area of air beds, an informal survey was conducted to identify common dimensions sold by various internet retailers. Twin-, queen-, and king-sized air beds are commonly sold, and commonly observed dimensions for these products were used to develop estimates for surface area for the low-, medium-, and high-exposure scenarios. The dimensions used are as

follows: a twin air bed is 75” × 39” × 9”, a queen air bed is 80” × 60” × 9”, and a king air bed is 80” × 76” by 9”. The general approach involved calculating the total surface area by summing the areas of the top and four side surfaces, excluding the bottom surface, which is not expected to emit to air. The total surface areas used in low-, medium-, and high-exposure scenarios were 3.9 m^2, 5.9 m^2, and 7.4 m^2.

It should be noted that the exposure to all products and articles, including air beds, were estimated by life stage (also known as age groups), including for infants under 1 year of age. According to the U.S. Consumer Product Safety Commission (CPSC), air beds should not be marketed or used by infants (CPSC, 2012). A review of air bed consumer labeling also highlighted that air beds are not intended for use by infants between the ages of 0 to 15 months due to a risk of suffocation during sleep (ASTM F2755 − 22). For this reason, EPA will only consider infant exposures and risks related to the use of air beds when considering PESS or sentinel exposures whereby, for example, some low-income families may still allow for infants to use air beds due to the lower cost, easier access, and versatility of air beds.

2.2.3.1.5 Car Mats

Based on a survey of car mat sets available on manufacturers websites, there was little variability in surface area. Mats are typically sold in sets, with two front mats ~30” × 20” and two back floor mats ~20” × 20”. Based on these dimensions the total surface area modeled was 1.29 m^2. As there was little observed variation in dimensions, this single value was used in the low-, medium-, and high-exposure scenarios.

2.2.3.1.6 Shower Curtains

Based on a survey of shower curtains available on manufacturers websites, there was little variability in surface area. EPA used manufacturer specifications for a shower curtain’s dimensions (1.83 m × 1.78m) to estimate surface area and multiplied by 2 to account for both sides. As there was little variability for this item, this single surface area value was used in the low-, medium-, and high-exposure scenarios.

2.2.3.1.7 Article Collections

Children’s toys and insulated wires generally have a small surface area for an individual item, but consumers may have many of the same type of item in their home. As phthalates are ubiquitous in PVC material, it is reasonable to assume that in a collection of toys or insulated cords and cables, all of the items may have DEHP content. As such, surface area for these items was estimated by assuming that a home has several of these items rather than one.

Surface area of wire insulation in the home was calculated using a typical circumference of wire insulation for cords (6.36 mm based on manufacturer specifications for 6 AWG wire size), typical length of cord (2 m, based on professional judgment), and estimated number of cords for various applications (appliances, electrical devices, internet, etc.) in a 1-, 2-, or 6-person household. The EPA estimated number of cords is 35, 48, and 92 for the low, medium, and high-end scenarios, respectively, which is supported by a 2014 Korean study (Won and Hong, 2014).

The surface area of new and legacy toys was varied for the low-, medium-, and high-exposure scenarios based on EPA’s professional judgment of the number and size of toys collected in a bedroom. Low, medium, and high estimates, respectively, were based on 5 small toys measuring 15 cm × 10 cm × 5 cm, 20 medium toys measuring 20 cm × 15 cm × 8 cm, or 30 large toys measuring 30 cm × 25 cm × 15 cm.

Table 2-6. Summary of Key Parameters for Inhalation and Dust Ingestion Exposure to DEHP from Articles Modeled in CEM 3.2

Article	Exposure Scenario Level	Weight Fraction [a]	Density (g/cm^3) [b]	Article Surface Area (m^2) [c]	Surface Layer Thickness (cm) [d]	Use Environment [e]	Volume (m^3) [d]	Interzone Ventilation Rate (m^3/h) [d]
Air beds	High	0.30	1.4	7.2	0.01	Whole house	492	1E−30
	Medium	0.11		5.9				
	Low	0.00003		3.9				
Car mats	High	0.13	1.4	1.29	0.01	Auto	2.4	9.5
	Medium	0.11						
	Low	0.087						
Children's toys (legacy) [f]	High	0.33	1.4	9.45	0.01	Bedroom	36	107
	Medium	0.023		2.32				
	Low	0.0000083		0.28				
Children's toys (new) [f]	High	0.0001	1.4	9.45	0.01	Bedroom	36	107
	Medium			2.32				
	Low			0.28				
Furniture components (textile)	High	0.39	1.4	17	0.01	Living room	50	109
	Medium	0.12		12				
	Low	0.00002		7.9				
Insulated cords	High	0.14	1.4	3.7	0.01	Whole house	492	1E−30
	Medium			1.9				
	Low			1.4				
Shower curtains	High	0.48	1.4	6.5	0.01	Bathroom	15	107
	Medium	0.18						
	Low	0.0005						
Vinyl flooring	High	0.028	1.4	202	0.01	Whole house	492	1E−30
	Medium	0.014		101				
	Low	0.000049		50.5				
Wallpaper (in place)	High	0.00004	1.4	200	0.01	Whole house	492	1E−30
	Medium	0.000025		100				
	Low	0.00001		50				

[a] See Section 2.1.1 for weight fraction sources and discussion.
[b] Used density of PVC from various sources, see *DEHP Consumer Exposure Analysis Spreadsheet* (U.S. EPA, 2025c).
[c] See text related to article in this section.
[d] CEM default for the emission scenario and saved analysis.
[e] Professional judgment based on likeliness of article presence.
[f] Toys scenarios consider an application of the CSPC final phthalates rule established in 2017 (16 CFR part 1307) that bans children's toys and childcare articles from containing more than 0.1% of DEHP. Therefore, toys currently on the market had weight fractions that did not exceed 0.1%. Legacy toy scenarios considered weight fractions in toys that were not limited to 0.1%.

2.2.3.1.8 Mouthing

For mouthing exposure, key parameters include the rate of chemical migration from the article to saliva ($\mu g/cm^2/h$), surface area mouthed (cm^2), and duration of mouthing (min/day). Derivation of these inputs is outlined in the sections below.

2.2.3.1.9 Chemical Migration Rate

Phthalates added to plastic products are not chemically bound to the polymer matrix, allowing for migration through the material and release into saliva during mouthing. The rate of phthalate migration and release to saliva depends upon several factors, including physicochemical properties of the article polymer matrix, phthalate concentration in the polymer, physical mechanics of the individual's mouth during mouthing (*e.g.*, sucking, chewing, biting, etc), and chemical makeup of saliva. In addition, physicochemical properties of the specific phthalate such as size, molecular weight, and solubility have a strong impact on migration rate to saliva.

Chemical migration rates of phthalates to saliva may be measured by *in vitro* or *in vivo* methods. Although measurement assays may be designed to mimic mouthing conditions, there is not a consensus on what constitutes standard mouthing behavior. As a result, there is considerable variability in assay methods, which is expected to affect the results. Because of the aggregate uncertainties arising from variability in physical and chemical composition of the polymer, assay methods for *in vitro* measurements, and physiological and behavioral variability in *in vivo* measurements, migration rates observed in any single study were not considered adequate for estimating this parameter. The chemical migration rate of DEHP was estimated based on data compiled in a review published by the Danish EPA in 2016 (DTI, 2016). For this review, data were gathered from existing literature for *in vitro* migration rates from soft PVC to artificial sweat and artificial saliva, as well as *in vivo* tests when such studies were available. The authors used 87 values from 4 studies (Babich et al., 2020; Niino et al., 2003; Bouma and Schakel, 2002; Fiala et al., 2000) for chemical migration rates of DEHP to saliva from a variety of consumer goods measured with varying mouthing approaches. These values were then subdivided into mild, medium, and harsh categories, with harsh amounts of mouthing or chewing of an article corresponding to the most vigorous oral exposure relative to mild amounts, based on the mouthing approach used to estimate migration as shown in Table 2-7.

There is considerable variability in the measured migration rates, but there was not a clear correlation between weight fraction of DEHP and chemical migration rate. As such, the same chemical migration rates were applied to all articles regardless of DEHP weight fraction. Mean values for chemical migration rates of DEHP under mild, medium, and harsh assay conditions were used in the low-, medium-, and high-exposure scenarios, respectively, and these values are expected to capture the range of reasonable values for this parameter. EPA calculated a high-intensity use of adult toys using harsh mouthing approaches as part of the screening approach; however, recognizing that this highly conservative use pattern is very unlikely behavior, it is not to be used to estimate risk. EPA did not identify use pattern information regarding adult toys.

Table 2-7. Chemical Migration Rates Observed for DEHP Under Mild, Medium, and Harsh Extraction Conditions

Mouthing Approach	Migration Rate (µg/cm^2/h) [a]		
	Minimum	Mean (Standard Deviation)	Maximum
Mild	0.002	0.27[b] (0.62)	3.31
Medium	0.04	10.7[b] (7.99)	31.3
Harsh	4.4	54.9[b] (41.0)	118

[a] Information from Tables 17, 18, and 19 in (DTI, 2016)
[b] Selected values for assessment.

2.2.3.1.10 Mouthing Surface Area

The parameter "mouthing surface area" refers to the specific area of an object that comes into direct contact with the mouth during a mouthing event. A standard value of 10 cm^2 for mouthing surface area (OECD, 2019) is commonly used in studies to estimate mouthing exposure in children. This standard value is based on empirical data reflecting typical mouthing behavior in young children, providing a reliable basis for estimating exposure levels and potential health risks associated with mouthing activities. The value of 10 cm^2 was therefore chosen for use in all mouthing exposure models for children.

Mouthing of adult toys was only modeled for adults and teenagers. Object mouthing is not commonly observed behavior in adults and teens, and as such there are not standard values for mouthing surface area. Although mouthing is uncommon for adults and teenagers, EPA assessed this potential behavior for adult toys only to consider associated exposures for selected individuals who may exhibit this behavior. The Agency did not identify adult toys use information with regards to surface area. To determine a reasonable value for mouthing surface area for adults and teens, EPA identified two studies that reported the surface area of the entire oral cavity in adults (Assy et al., 2020; Collins and Dawes, 1987). The mean surface area reported in Collins and Dawes (1987) was 215 cm^2 and the mean value reported in Assy et al. (2020) was 173 cm^2. Based on these data, EPA assumes approximately 200 cm^2 is a reasonable estimate for the total surface area in the oral cavity. However, this value accounts for all surface area—including teeth, gums, the ventral surface of the tongue, and mouth floor—which is a significant overestimation of surface area that would be in contact with an object. As such, it was assumed that 50 percent of the total surface area might reasonably represent mouthing surface area, and a value of 100 cm^2 was used for this parameter. This corresponds approximately with a one-ended cylinder having a radius of 2 cm and length of 7 cm. This value is similar, though slightly lower than the value of 125 cm^2 used for adult toy mouthing area in the European Chemicals Agency (ECHA) assessment.

2.2.3.1.11 Mouthing Duration

Mouthing duration values for this assessment were derived from EPA's *Exposure Factors Handbook*, Table 4-23 (U.S. EPA, 2011c), which provides mean mouthing durations for children aged 1 month to 5 years. These values, originally sourced from (Smith and Norris, 2003), are categorized by age group and item type, including toys, pacifiers, fingers, and other objects. For this assessment, mouthing durations for toys were applied to both legacy and new children's toys, while durations for "other objects" were used for items such as insulated wire, synthetic leather furniture, and rubber erasers.

Mouthing duration from Table 4-23 of the *Exposure Factors Handbook* (U.S. EPA, 2011c) were modified to accommodate input into CEM. More specifically, the data provided in Handbook was broken down into more age groups than CEM allows for with modeling. For example, it provides different mouthing durations for infants 12 to 15 months, 15 to 18 months, 18 to 21 months, and 21 to 24 months of age; CEM, in contrast, has only one age group for infants under 1 year of age. To determine mouthing durations appropriate for use in CEM, all relevant data in the Handbook were considered together. The minimum value by item type within each age group was used in the low-exposure scenario, the maximum value was used in the high-exposure scenario, and the mean value (average across the age groups provided in the Handbook (U.S. EPA, 2011c)) was used in the medium-exposure scenario, as shown in Table 2-8.

In addition, the mouthing duration values from Table 4-23 of the Handbook were further modified to better reflect the time spent mouthing materials likely to contain phthalates. While Smith and Norris (2003) provides robust data on total mouthing time, the study reported that a wide variety of objects

were mouthed, with plastic items making up approximately 15 percent of mouthed objects in children aged 1 to 3 months, increasing to 50 percent by 6 to 9 months, and remaining at this level through 5 years of age. However, these percentages reflect the fraction of total mouthing time spent on plastic items without distinguishing between plastic types. Because soft plastic items likely make up only a portion of the total plastic category, the reported durations for plastic mouthing time are likely higher than what would be expected for items with significant plasticizer content.

To better estimate time spent mouthing soft plastic items, the Smith and Norris values were adjusted using data from Greene (2002), which specifically provided mouthing times that distinguished between soft plastic and other materials. Their data indicate that among items classified as soft plastic toys, teethers, and rattles soft plastic items accounted for 15 to 21 percent of total mouthing time in 3- to 12-month-olds, 21 to 26 percent in 12- to 24-month-olds, and 30 to 41 percent in 24- to 36-month-olds. Although the total daily mouthing durations reported in these two studies may differ due to differences in study design, the proportion of time spent mouthing soft plastic relative to total mouthing time can be largely attributed to factors unlikely to differ between studies (*e.g.*, toy manufacturing and availability, oral exploration as a developmental behavior, teething discomfort). As such, EPA assumes that the values for time spent mouthing soft plastic items relative to total mouthing time reported in Greene (2002) is representative of the distribution in Smith and Norris (2003). Furthermore, values reported in Table 4-23 of the Handbook were adjusted to 41 percent of the total duration. As this was the highest value reported across all age groups, it is assumed that this will provide a health-protective estimate of soft plastic mouthing durations. A detailed description of the strengths and limitations of both studies and is provided in Section 5.1.

For mouthing of adult toys, values of 60, 30, and 15 minutes per day were used in the high-, medium-, and low-exposure scenarios, respectively. Because there were no available data for these values, they were chosen to encompass the range of expected mouthing durations based on professional judgment.

Table 2-8. Mouthing Durations for Children for Toys and Other Objects

	Estimated Mean Daily Mouthing Duration Values, Soft Plastic Items (min/day) [a]				**Mouthing Durations for CEM Age Groups (min/day)**		
Item Mouthed	**Reported Age Group**				**CEM Age Group: Infants <1 Year**		
	1–3 Months	**3–6 Months**	**6–9 Months**	**9–12 Months**	**High Exposure Scenario [b]**	**Med. Exposure Scenario [c]**	**Low Exposure Scenario [d]**
Toy	0.4	11.6	16.1	9.5	16.1	9.4	0.4
Other object	2.1	5.1	10.0	6.7	10.0	6.0	2.2
Item Mouthed	**Reported Age Group**				**CEM Age Group: Infants 1–2 Years**		
	12–15 Months	**15–18 Months**	**18–21 Months**	**21–24 Months**	**High Exposure Scenario**	**Med. Exposure Scenario**	**Low Exposure Scenario**
Toy	6.3	6.8	4.6	6.5	6.8	6.0	4.6
Other object	4.9	9.4	8.1	5.3	9.4	6.9	4.9
Item Mouthed	**Reported Age Group**				**CEM Age Group: Small Child 3–5 Years**		
	2 Year	**3 Year**	**4 Year**	**5 Year**	**High Exposure Scenario**	**Med. Exposure Scenario**	**Low Exposure Scenario**
Toy	5.1	4.8	1.3	0.8	5.1	3.0	0.8
Other object	8.9	6.3	4.4	4.1	8.9	5.9	4.10

[a] Table 4-23 in *Exposure Factors Handbook*, adjusted to 41% of total reported values to represent mouthing of soft plastic

	Estimated Mean Daily Mouthing Duration Values, Soft Plastic Items (min/day) [a]	Mouthing Durations for CEM Age Groups (min/day)
[b] High-exposure scenario value was the largest of the reported mouthing durations for each age group. [c] Med. (medium)-exposure scenario was calculated as the mean of the high and low exposure scenarios selected values. [d] Low-exposure scenario value was the lowest of the reported mouthing durations for each age group.		

2.2.3.2 Key Parameters for Liquid and Paste Products Modeled in CEM

CEM models for liquid and paste products only evaluated exposure by inhalation, while dermal exposures were modeled outside of CEM, see Section 2.3. Higher concentrations of DEHP in air and dust will result in increased inhalation exposure. This may occur due to product formulation or use patterns that allow for higher emissions of DEHP to air, and/or environment-specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control DEHP emission rates from products in CEM 3.2 models are weight fraction of DEHP in the formulation, duration of product use, mass of product used, and frequency of use. Any increase in these parameters will result in higher chemical exposure from product use. CEM defaults were used for all environmental parameters in product models. A detailed description of derivations of all other key parameter values used in CEM 3.2 models for liquid and paste products is provided below, and a summary of values be found in Table 2-9. Note that products not modeled for inhalation exposure are not included in the table.

Mass of Product Used

For liquid and paste products used for home and auto maintenance and/or repair projects, the mass of product used in each scenario was based on the reasonable assumption that the volume in which products are sold is adequate for the tasks for which they are intended. Mass of product used inputs was based on a survey of consumer available products fitting the COU description on manufacturers websites; see DEHP Use Report Information tab (links and products available) in *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025d). This section summarizes the identified information for each product. For high-exposure scenarios, it was assumed that the entire mass of the largest product container sold is used, reflecting scenarios where a large project or extensive application is undertaken. Medium-exposure scenarios represent more common or average usage for routine maintenance or smaller projects. Low-exposure scenarios represent minimal use for minor repairs or touch-ups. This approach is consistent with observations of consumer reviews for individual products on vendor websites, which indicated diverse usage patterns among consumers including small, medium, and large projects.

The concrete sealant product identified with DEHP content is sold in 1- and 5-gallon buckets; the high-exposure scenario assumes the full 5-gallon bucket was used, medium-exposure scenario assumes 2.5 gallons were used, and the low-exposure scenario assumes the full 1-gallon bucket was used. Products for exterior coatings on vehicles were sold in 6-quart (1.5-gallon), 1-gallon, and 16.5-ounce formats; these volumes were assumed for low-, medium-, and high-exposure scenarios, respectively. Flooring adhesive is sold in 4-gallon buckets; low-, medium-, and high-exposure scenarios assume that a full, half, or quarter container are used, respectively.

Duration and Frequency of Product Use

Duration of use inputs was based on a survey of consumer available products fitting the COU description on manufacturers websites; see DEHP Use Report Information tab (links and products available) in *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025d). This section summarizes the identified information for each product. To determine reasonable values for the duration of time products are used during each use

event, information from label instructions, consumer reviews for individual products on vendor websites, and professional judgment was aggregated to develop estimates for a reasonable range of values that reflect the variability in use patterns for each product.

The flooring adhesive and concrete sealant products are potentially used for large scale home maintenance projects such as installation of building materials and finishing of large surface areas. As such, the high estimate for use time was assumed to be a full 8-hour day, and medium and low estimates were set at 4 and 2 hours to reflect usage for smaller scale projects. As automobile coatings were expected to be used for relatively small projects, the high-estimate for use time was assumed to be 2 hours, while the medium- and low- estimates were 1 hour and 30 minutes, respectively. These values are slightly higher than CEM default values for aerosol spray paints (90, 45, and 15 minutes), but are intended to reflect the variability in use indicated by the consumer reviews on e-commerce sites.

The products modeled for inhalation exposure in this assessment are not common household products expected to be used on a routine basis. For flooring adhesive, auto repair putty, and concrete sealant products, label instructions and purchaser reviews indicate that these products are used primarily for large scale repair and DIY projects requiring significant preparation and clean up. As such, these products are anticipated to be used once per year, but two full days may be required to accommodate large surface area applications and/or multiple coat applications. For auto coatings, label instructions and purchaser reviews indicate that these products may be used for a variety of projects ranging from small to large in scale. As such, these products were modeled for weekly use under the assumption that they may be used routinely for hobby and DIY repair projects.

Table 2-9. Summary of Key Parameters for Products Modeled in CEM 3.2

Product	Exposure Scenario Level	Weight Fraction [a]	Density (g/cm^3) [b]	Duration of Use (Min) [c]	Product Mass Used (g) [c]	Chronic Freq. of Use ($year^{-1}$)	Acute Freq. of Use (day^{-1})	Use Environ.; Volume (m^3) [c]	Air Exchange Rate, Zone 1 and Zone 2 (hr^{-1}) [d]	Interzone Ventilation Rate (m^3/h) [d]
Auto coatings	High	0.05	0.955	120	5,421	52	1	Garage; 90	0.45	108.978
	Med	0.0165		60	3,615					
	Low	0.003		30	441					
Concrete sealant	High	0.002	0.95	480	19,682	2	1	Outside; 1E100	0.45	1E−30
	Med	0.0015		240	11,809					
	Low	0.001		120	3,936					
Flooring adhesive	High	0.3	0.726	480	17,714	2	1	Whole House; 492	0.45	1E−30
	Med	0.225		240	8,857					
	Low	0.15		120	4,428					

[a] See Section 2.1.2. High-intensity use value is the reported range maximum, the low-intensity use value is the reported range minimum, and the medium-intensity use value is the mean from the reported maximum and low.
[b] Used SDS-reported product density value, see *DEHP Consumer Analysis* Supplemental Spreadsheet, (U.S. EPA, 2025c).
[c] Use environment was determined based on product manufacturer use description in U.S. EPA (2025d) DEHP Use Report Information tab.
[d] CEM default. For all scenarios, the near-field modeling option was selected to account for a small personal breathing zone around the user during product use in which concentrations are higher, rather than employing a single well-mixed room. A near-field volume of 1 m^3 was selected.

2.3 Dermal Modeling Approach

This section summarizes the available dermal absorption data related to DEHP, the interpretation of the dermal absorption data, dermal absorption modeling efforts, and uncertainties associated with dermal absorption estimation in Section 5. Although inhalation and ingestion pathways were modeled using CEM, see Section 2.2, dermal modeling was conducted outside of CEM. The use of the CEM Model for dermal absorption, which relies on total concentration rather than aqueous saturation concentration, would greatly overestimate exposure to DEHP in liquid and solid products and articles See U.S. EPA (2025b) for more detail. The dermal modeling for liquid and solid products was conducted using the approach described below. Dermal data were sufficient to characterize consumer dermal exposures to liquids or formulations as well as to solids or articles containing DEHP (Section 2.3.1). Dermal exposures to vapors are not expected to be significant due to the extremely low volatility of DEHP; therefore, they are not included in the dermal exposure assessment of DEHP.

2.3.1 Dermal Absorption Data

Dermal absorption data related to DEHP were identified in the literature. Specifically, EPA identified nine studies directly related to the dermal absorption of DEHP. Of the nine available studies, EPA identified two studies that are most reflective of DEHP exposure from consumer products and articles: one for liquid products (Hopf et al., 2014) and one for solid products (Chemical Manufacturers Association, 1991) (technical report). (Note that Deisinger et al. (1998) is a peer-reviewed publication that contains some of the 1991 report information above, it also uses the criteria listed below.) The following list summarizes the criteria used to select Hopf et al., (2014) and Chemical Manufacturers Association (1991) among the identified studies as the most reflective of DBP dermal exposure from liquid products:

- Recent studies were preferred that used modern dermal testing techniques and guidelines for *in vivo* and *in vitro* dermal absorption studies (*i.e.,* OECD Guideline 427 (OECD, 2004a) and Guideline 428 (OECD, 2004b)).
- Studies of human skin were preferred over animal models, and when studies with human skin were not suitable (see other criteria), studies of guinea pig skin were preferred over rat studies. Guinea pig skin absorption is closer to human skin than rats, per OECD 2004a).
- Studies with metabolically active skin were preferred to studies with non-viable skin samples.
- Studies with dermal loading rates sufficient to estimate absorptive flux were preferred. Flux values derived from studies with high values of fractional absorption may lead to overestimation of dermal absorption.
- Studies with exposure times that are relevant or closer to dermal durations used in the consumer exposure assessment were preferred, see Section 2.3.3.
- Studies with reported sample temperatures that represent human body temperature, in a humidity-controlled environment, were also preferred.

EPA's rationale for the selection of the studies and parameters for use in risk assessment is described in Section 2.1.2 in U.S. EPA (2024), whereas U.S. EPA (2024) provides a detailed description of each DEHP dermal study identified and conclusions on the selected dermal study.

2.3.1.1 Dermal Absorption Data for Liquids

The Hopf et al. (2014) is an *ex vivo* human study and the most recent of its kind from EPA's pool of dermal hazard studies. Compared to other dermal studies, skin samples used in the Hopf et al. (2014) study were the most viable as they were used for assay initiation within 2 hours of excision. The skin samples were also metabolically active at the time of testing. The testing temperature was 32 °C, which is relatively close to human bodily temperatures. Although humidity was not reported, overall, the study

complies with OECD guideline 428. This study was given a medium-quality rating.

2.3.1.2 Dermal Absorption Data for Solids

The Chemical Manufacturers Association (1991) study is an *in vivo* rat study and the only one applicable to the solid-to-skin scenario (via PVC film applied to rats' skin). Use of this study would allow EPA to circumvent the need to estimate exposures from the article to dust followed by sweat (assuming the most conservative aqueous partitioning coefficient used to simulate sweat) as well as DEHP transfer from the sweat to/through the skin. The assessment methodology mostly agreed with guideline OECD 427, except that blood was not collected and analyzed. This study was rated medium-quality overall.

For the specific assessment of exposure to DEHP from contact of adult toys with mucosal membranes, EPA considered (Britz et al., 1980), as suggested by the Science Advisory Committee on Chemicals (SACC) (U.S. EPA, 2025i). This study provides some insight on the differences in absorption between skin types. (Britz et al., 1980) provided a comparison of absorption of hydrocortisone in the forearm compared to the vulvar skin (labia majora) of five women. The urinary excretion of radiolabeled hydrocortisone percent dose was larger for vulvar skin than for forearm skin for exposures measured at 6, 12, and 24 hours. The vulvar skin percent of dose rapidly decreased until it was comparable yet higher to forearm absorption after 3 days. This study indicates that vulvar skin may have higher absorption than forearm skin. However, the study results showed high inter-individual variability of absorption. In addition, the shortest exposure duration experiment in the study was for 0 to 6 hours, which gretl exceeds exposure durations used for adult toys in this assessment (15, 30, and 60 minutes; see Table 2-11 for details).

Although the (Britz et al., 1980) study provides insight into the increased potential for absorption through vulvar skin as compared to forearm skin, the study had a small sample size, high inter-individual variability, and studied longer exposure durations than would be expected for use of adult toys. Additionally, there may be differences in permeability of vulvar skin (labia majora) compared to the vaginal or anal mucosa, where adult toys may be in contact. All of these factors make the study inappropriate for use in an extrapolation to absorption of phthalates due to contact with vaginal and anal mucosa.

2.3.1.3 Dermal Absorption Data Interpretation

With respect to interpretation of the DEHP dermal absorption data reported in Hopf et al. (2014) and Chemical Manufacturers Association (1991), it is important to consider the relationship between the applied dermal load and the rate of dermal absorption. Specifically, the work of Kissel (2011) suggests the dimensionless term N_{derm} to assist with interpretation of dermal absorption data. The term N_{derm} represents the ratio of the experimental load (*i.e.*, application dose) to the steady-state absorptive flux for a given experimental duration as shown in the following equation:

Equation 2-1. Relationship Between Applied Dermal Load and Rate of Dermal Absorption

$$N_{derm} = \frac{experimental\ load\ (\frac{mass}{area})}{steady-state\ flux\ \left(\frac{mass}{area * time}\right) \times\ experimental\ duration\ (time)}$$

Kissel (2011) indicates that high values of N_{derm} (>>1) suggest that supply of the material is in excess and that the dermal absorption is considered "flux-limited," whereas lower values of N_{derm} indicate that absorption is limited by the experimental load and would be considered "delivery-limited." Furthermore,

Kissel (2011) indicates that values of percent absorption for flux-limited scenarios are highly dependent on the dermal load and should not be assumed transferable to conditions outside of the experimental conditions. Rather, the steady-state absorptive flux should be utilized for estimating dermal absorption of flux-limited scenarios.

DEHP's high molecular weight, large size, and low solubility in water impede its ability to cross the dermal barrier, limiting the rate of flux independent of the concentration on the skin. Furthermore, for flux-limited scenarios, a steady-state dermal flux is primarily governed by the chemical's ability to permeate the skin rather than the total applied dose (*i.e.*, dermal loading). Whereas the dermal surface concentration does influence flux to some extent, for DEHP its impact is expected to be relatively small compared to the fundamental transport limitations imposed by the skin barrier. Therefore, the steady-state flux value derived from experimental data should be reasonable for estimating absorption across consumer products and articles, despite variability in formulation concentration. If sufficient surface concentration is present to sustain diffusion, differences in loading should not meaningfully impact the absorption rate.

Hopf et al. (2014) reported a steady-state flux of 2.50×10^{-5} mg/cm^2/h through the application of DEHP from an aqueous solution to excised human skin. However, it should be noted that though the reported applied dose was 140.7 mg/cm^2, this may be an error. Based on the other information reported (*i.e.*, a concentration of 166 µg/mL, application of 1.5 mL, and a skin surface area of 1.77 cm^2), the applied dose would be 140.7 µg/cm^2 (166 µg/mL × 1.5 mL = 249 µg; 249 µg/1.77 cm^2 = 140.7 µg/cm^2). Therefore, based on this information, a dose of 140.7 µg/cm^2 (or 1.41×10^{-1} µg/cm^2) was used to calculate N_{derm}. The application of N_{derm} to the DEHP dermal absorption data reported in Hopf et al. (2014) is shown below.

$$N_{derm} = \frac{0.1407\ mg/cm^2}{0.000025\ mg/cm^2/hr\ \times 24\ hr} = 234.5$$

Chemical Manufacturers Association (1991) reported a dose of 26.7 mg/cm^2 of DEHP over a 24-hour period, and a steady-state flux of 4.80×10^{-5} mg/cm^2/h from ^{14}C-DEHP plasticized PVC films applied to rat skin that were used to calculate N_{derm}. The application of N_{derm} to the DEHP dermal absorption data reported in Chemical Manufacturers Association (1991) is shown below.

$$N_{derm} = \frac{26.7\ mg/cm^2}{0.000048\ mg/cm^2/hr \times 24\ hr} = 23100$$

Because N_{derm} >> 1 for the experimental conditions of each study (Hopf et al., 2014; Chemical Manufacturers Association, 1991), it is shown that the absorption of DEHP is considered flux-limited even at finite doses (*i.e.*, less than 10 µL/cm^2 (OECD, 2004b)). Although the steady-state flux value reported by Chemical Manufacturers Association (1991) is representative of exposures to solid articles, the steady-state flux value reported by Hopf et al. (2014) is representative of exposures to liquid products. As such, the appropriate steady-state flux value for products (4.80×10^{-5} mg/cm^2/h) and articles (2.50×10^{-5} mg/cm^2/h) was applied accordingly in all relevant exposure models for DEHP.

2.3.2 Dermal Absorption Refinement Approach for Air Beds

EPA used the flux-limited approach as a screening approach and then developed a refined dermal analysis for dermal exposures for air beds. Both dermal approaches used a range of conservative input parameters for contact surface area, contact between skin and air bed, and duration and frequency of exposure. The screening approach may best represent select populations (*i.e.*, low income) who may use

air beds without sheets. The flux-limited screening dermal absorption approaches for liquid and solid products and articles assumes an excess of DEHP in contact with the skin independent of concentration in the article. EPA added a refined dermal exposure assessment for air beds that considered the use of a bedsheet barrier between skin and air bed. In addition, the Agency considers refinement of exposure scenarios if potential risk is identified in connection with certain uncertainties in the screening approach can be further quantified. Potential risk is identified when the margin of exposure (MOE) is under the benchmark (<30); see Appendix B for results and discussion of the screening and refined approach results. The dermal absorption refined approach models dermal absorption using DEHP concentration in air bed, material (air bed and bedsheet) DEHP-specific partition coefficients, and a barrier bedsheet between air bed and skin, which provides a more accurate representation of dermal absorption of DEHP.

In summary, the methodology for estimating dermal flux of DEHP from air beds was adapted from previous studies, see Table 2-10 on dermal exposure to phthalates mediated by clothing layers, and considering the concentration of DEHP in article. The approach assumes equilibrium partitioning between the air bed material, an adjacent boundary layer of air, the bedsheet, and the overlying air layer in contact with skin. DEHP emission from the air bed into the boundary layer of air was assumed to reach steady-state conditions, facilitating partitioning into the bedsheet. Subsequently, DEHP diffuses through the bedsheet and partitions into the thin air layer at the sheet's surface. In this refined approach several constants from various sources were used to calculate dermal absorption due to exposure to air beds. In this approach, lowercase k are used to denote rate constants and uppercase K are used to denote equilibrium constants.

The air bed dermal exposure model framework included two primary pathways for DEHP uptake: (1) direct absorption from the air layer adjacent to the sheet, and (2) absorption from the sheet material itself. The total dermal flux (J_{Total}) was expressed as the sum of these two contributions in Equation 2-2. See Table 2-10 for inputs and estimated results from the following equations.

Equation 2-2. Total Dermal Flux

$$J_{Total} = J_{Air} + J_{Bedsheet-Skin}$$

Where:

J_{Air}	=	Flux from the air layer adjacent to the bedsheet
$J_{Sheet-Skin}$	=	F the flux from the sheet material.

For flux from the air layer (J_{Air}), the concentration of DEHP in the air layer above the sheet, C_{Air-1}, µg/m^3 (estimated with Equation 2-4) and the skin permeability coefficient for air-phase transfer, k_{Air}, 139 m/day (Li et al., 2019; Weschler and Nazaroff, 2012), and the fraction of the contact area, 0.75 (conservative assumption), were used per Equation 2-3.

Equation 2-3. Air Layer Adjacent to Sheet Flux

$$J_{Air} = C_{Air-1} \times k_{Air} \times (1 - f)$$

The concentration of DEHP in the air above the sheet, C_{Air-1}, can be estimated from the DEHP concentration in the air bed, $C_{Air\ bed}$, which is obtained from (DTI, 2010), and the partition coefficient from PVC air bed article to air, $K_{Air-Bed}$, 4.31×10^{-11}, which was obtained from Gilliam et al. (2022) per Equation 2-4.

Equation 2-4. Concentration of DEHP in Air Above Sheet

$$C_{Air-1} = C_{Airbed} \times K_{Air-Bed}$$

For flux from the bedsheet, $J_{Bedsheet-Skin}$, the concentration in the skin, C_{Skin}, µg/m^3, was used and estimated using Equation 2-7, with skin permeability coefficient for air-phase transfer, $k_{Skin,}$ m/day, per Equation 2-5. k_{Skin}, value was taken from Li et al. (2019) and Gong et al. (2014), 9.6×10^{-8}, and the fraction of contact area, 0.75 (conservative assumption).

Equation 2-5. Flux from Sheet Material

$$J_{Bedsheet-Skin} = C_{Skin} \times k_{Skin} \times f$$

The DEHP concentration in the skin, C_{Skin}, µg/m^3, was determined by the equilibrium partitioning from the bedsheet and the concentration in the bedsheet, per Equation 2-6. The concentration in the bedsheet was estimated using Equation 2-7; for the equilibrium partitioning coefficient between sheet and air layer, EPA used Equation 2-8.

Equation 2-6. DEHP Concentration in Skin from Bedsheet

$$C_{Skin} = C_{Bedsheet} \times K_{Skin-Bedsheet}$$

The DEHP concentration in the sheet, $C_{Bedsheet}$, was determined by equilibrium partitioning from the sheet to air, per Equation 2-7. The concentration in the air between the sheet material and skin, C_{Air-2}, can be estimated from the equilibrium partitioning between the sheet and the air layer. C_{Air-1} and C_{Air-2} are assumed to reach equilibrium and therefore are the same value. The equilibrium is controlled by the partition coefficient, $K_{Bedsheet-Air}$, and the concentration of DEHP in the sheet material, $C_{Bedsheet}$, per Equation 2-7. $K_{Bedsheet-Air}$, value was from Li et al. (2019) and Saini et al. (2016), 3.98×10^{-8}. Although C_{Air-1} and C_{Air-2} are in equilibrium and are expected to be the same value, EPA labeled each differently to represent the various surfaces and phases in consideration contributing to these concentrations and assumptions through the calculation.

Equation 2-7. DEHP Concentration in Sheet

$$C_{Bedsheet} = {}^{C_{Air-2}}/_{K_{Bedsheet-Air}}$$

For the partition coefficient between bedsheet and air layer, $K_{Skin-Bedsheet}$, EPA used Equation 2-8 which resulted in $K_{Skin-Bedsheet}$ equal to 100. $K_{Skin-Air}$ value was from Huang et al. (2022), 2.51×10^{9}, whereas the $K_{Air-Bedsheet}$ value was from Li et al. (2019) and Saini et al. (2016), 3.98×10^{-8}.

Equation 2-8. Partition Coefficient Between Bedsheet and Skin

$$K_{Skin-Bedsheet} = K_{Skin-Air} \times K_{Air-Bedsheet}$$

This modeling framework assumes that partitioning at each interface reaches equilibrium and that the emission rate of DEHP from the air bed is sufficient to maintain steady-state conditions. Parameter values for partition coefficients and permeability constants were obtained from the literature to ensure consistency with experimental data for DEHP and similar phthalates. Table 2-10 summarizes the values

from literature and the references. This approach enabled estimation of dermal flux under conditions representative of air bed use, considering the bedsheet as a barrier layer. The approach includes low-, medium-, and high-intensity use exposure scenarios. The scenarios consider the range of air bed DEHP concentrations (see Table 2-10) and the subsequent calculated parameters that branch out into low-, medium-, and high-intensity use exposure inputs and outputs from the air bed DEHP concentrations.

Table 2-10. Air Beds Refined Dermal Exposure Input Parameters

Parameter, Symbol, and Units	Low-, Medium-, and High-Intensity Use Scenario Inputs and Outputs			Source(s) and Associated Equation
	Low	Medium	High	
DEHP concentration in the air bed, C_{Airbed}, µg/m^3	4.2E07	1.6E11	4.3E11	(DTI, 2010), Equation 2-4
Partition coefficient from PVC air bed article to air, $K_{Air\text{-}Bed}$, Unitless	4.31E−11			(Gilliam et al., 2022), Equation 2-4
DEHP concentration in air above sheet, $C_{Air\text{-}1}$ (in steady-state equilibrium with $C_{Air\text{-}2}$), µg/m^3	1.81E−03	6.68	18.3	Equation 2-3 and Equation 2-4
Skin permeability coefficient for air-phase transfer, k_{Air}, m/day	139			(Li et al., 2019; Weschler and Nazaroff, 2012), Equation 2-3
Flux from the air layer adjacent to the bedsheet, J_{Air}, µg/m^2-day	**6.28E−02**	**2.32E02**	**6.37E02**	**Equation 2-3**
Partition coefficient between the sheet and the air layer, $K_{Air\text{-}Bedsheet}$ and $K_{Bedsheet\text{-}Air}$, Unitless	3.98E−08			(Li et al., 2019; Saini et al., 2016), Equation 2-8
Partition coefficient between skin and air, $K_{Skin\text{-}Air}$, Unitless	2.51E09			(Huang et al., 2022), Equation 2-8
Partition coefficient bedsheet and air, $K_{Skin\text{-}Bedsheet}$, Unitless	100			Equation 2-8
DEHP concentration in sheet and air in contact with skin, $C_{Air\text{-}2}$ (in steady-state equilibrium with $C_{Air\text{-}1}$), µg/m^3	1.81E−03	6.68	18.3	Equation 2-3, Equation 2-4, and Equation 2-7
DEHP concentration in sheet, $C_{Bedsheet}$, µg/m^3	4.54E04	1.68E08	4.60E08	Equation 2-7
Skin permeability coefficient for air-phase transfer, k_{Skin}, m/day	9.60E−08			(Li et al., 2019; Gong et al., 2014), Equation 2-5
Concentration in the skin, C_{Skin}, µg/m^3	4.54E06	1.68E10	4.60E10	Equation 2-6
Flux from the bedsheet, $J_{Bedsheet\text{-}Skin}$, µg/m^2-day	**0.327**	**1.21E03**	**3.31E03**	**Equation 2-5**
Total dermal flux, J_{Total}, µg/m^2-day	**3.9E−01**	**1.44E03**	**3.95E03**	**Equation 2-2**

2.3.3 Modeling Inputs and Parameterization

Key parameters for the dermal model include duration of dermal contact, frequency of dermal contact, total contact area, and dermal flux—an increase in any of these parameters results in an increase in exposure. Table 2-11 presents the key parameters used in the models. For contact area, professional judgment, based on product use descriptions from manufacturers and each article's typical use, was applied to determine reasonable contact areas for each product or article. In addition to considering typical product and article use, EPA used conservative contact area options with the possibility of further refining the scenario should risk be identified in Section 4 of the *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h). The subsections under Table 2-11 provide details

on assumptions used to derive other key parameters. Calculations, sources, input parameters and results are also available in *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025d). Acute and chronic dose calculations and equations are summarized in Appendix A.4.

Duration of Use/Article Contact Time

For liquid and paste products, it was assumed that contact with the product occurs at the beginning of the period of use and the product is not washed off until use is complete. Therefore, the duration of dermal contact for these products is equal to the duration of use applied in CEM modeling for products. For products not modeled in CEM (auto repair putty and inductance loop sealant), manufacturer instructions and customer reviews were considered to develop estimates. For inductance loop sealant, it was assumed that application for a large project could be a full day of work, while smaller projects may be accomplished more quickly. Thus, durations of use for low-, medium-, and high-exposure scenarios were assumed to be 120, 240, and 480 minutes, respectively. For auto repair putties, the small mass of product sold and generally small projects listed as potential uses indicated that these products was used for small-to-medium auto repair projects; thus, the dermal contact times used in low-, medium-, and high-exposure scenarios were 30, 60, and 120 minutes.

For articles that do not include duration of use as an input in CEM, professional judgment was used to select the duration of use/article contact for the low-, medium-, and high-exposure scenario levels. For vinyl flooring products, values for dermal contact time were based on EPA's Standard Operating Procedures for Residential Pesticide Exposure Assessment for the high-exposure level (2 hours; time spent on floor surfaces); ConsExpo for the medium-exposure level (1 hour; time a child spends crawling on treated floor); and professional judgment for the low1exposure level (0.5 hour) (U.S. EPA, 2012). For articles used in large home DIY projects (installation), it was assumed that a large project could be a full day of work, while smaller projects may be accomplished more quickly. Therefore, contact times for low-, medium-, and high-exposure scenarios were assumed to be 120, 240, and 480 minutes, respectively. Similarly, clothing and indoor furniture have the potential for long durations of dermal contact but may be also used for shorter periods and were thus modeled at 480, 240, and 120 minutes.

For synthetic leather furniture the input parameters in the high-intensity use scenario represent either mostly naked or a partly underdressed (50% of entire body) person laying or seating on the furniture for 8 hours (480 minutes), which may be an unrealistic behavior that is unlikely to be representative of actual synthetic leather furniture uses across lifestages. The high-, medium-, and low-intensity use scenario for infants are likely a misuse because infants should not be set on furniture for extended periods of time; thus, dermal exposure to infants from synthetic leather furniture is not expected. EPA has low confidence in using toddler lifestages 8- and 4-hour contact duration as it may be an extreme consideration and recommends using the low-intensity use contact duration for toddlers. The medium-intensity use scenario considers 25 percent of face, hands, and arms surface in contact with the furniture for 4 hours. The medium-intensity use scenario represents a dressed person either seating or laying on the furniture, which EPA assumes to be a more representative scenario for preschoolers and older lifestages whereas the low-intensity use scenario contact duration can be used for toddlers' upper-bound estimate. Outdoor furniture was considered less likely to be used for extended periods and was modeled at 120, 60, and 30 minutes per use. Values of 60, 30, and 15 minutes were assigned to articles anticipated to have low durations of contact such as car mats, rubber eraser, shower curtain, wire insulation, and routine (in-place) contact with wallpaper.

For the synthetic leather clothing, EPA assumed that these items would be in contact with the skin for 50 percent of entire body surface area for the high-intensity use scenario and 25 percent of face, hands, and

arms for the medium-intensity use scenario. There is uncertainty in assuming large skin contact for synthetic leather in the high-intensity use scenario. The use of 50 percent of entire body surface equates to contact with tops and bottom items of clothing. The use of synthetic leather tops and bottoms is possible; however, EPA is uncertain in the widespread use of these clothing items. The medium-intensity use scenario for synthetic leather clothing considers 25 percent of face, hands, and arms surface in contact with the clothing item and for 4 hours total. The medium-intensity use synthetic leather scenario represents clothing items similar to synthetic leather coats and accessories. EPA has a robust confidence that the medium-intensity use scenario inputs accurately represent expected uses.

For adult toys, EPA used Herbenick et al. (2023) to determine use durations. The study provides a summary of past surveys and their own survey about partnered sex duration. While the study collected information on use of adult toys among age groups and genders, the study was not clear about the duration of use of the adult toys. However, the durations of partnered sexual activity reported by the study were similar to the duration of use for adult toys used in the modeling. The mean duration of partnered sexual activity reported for all age groups and genders was approximately 30 minutes. The study reported on past surveys that reported partnered sex durations ranging from 15 to 57 minutes. EPA used 15, 30, and 60 minutes for duration of use for the low-, medium-, and high-intensity use exposure scenarios for adult toys, respectively. The adult toys dermal assessment considered handling of the article in which the surface area in contact corresponded to inside of two hands (palms and fingers).

The contact duration for some of the listed articles may seem extremely conservative and unlikely for some age groups. For example, in-place wallpaper high-intensity scenario contact for 60 minutes, may be plausible for children under 5 years that touch walls frequently and elderly people that touch walls for support and maintain balance, but less likely for young teens to adults. The medium- and low-intensity use scenarios may be more representative of common contact durations for young teens to adults. EPA's screening approach considers exposure scenarios using conservative input parameters. If risk is identified in the risk characterization stage of this assessment for the low-, medium-, and high-intensity use scenario, then further scenario refinement of inputs was considered; see Section 4 of the *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h).

For air beds, contact durations of 857, 480, and 120 minutes were applied. The 857-minute values correspond to the sleep times for 1- to 4-year-olds presented in the *Exposure Factors Handbook*; Table 16-26 (U.S. EPA, 2011c) of the Handbook was used for the high-intensity use exposure scenario. The 480- and 120-minute contact durations were used for the medium- and low-intensity use scenarios, respectively. EPA used professional judgment for using 480 minutes to represent an average nighttime sleeping pattern, and 120 minutes to represent an average nap time. To estimate contact time with children's toys, data were obtained from the Children's *Exposure Factors Handbook* Table 16-26 (U.S. EPA, 2011c). Reported values for playtime for children under 15 ranged from 24 minutes/day to 137 minutes/day, with a mean value of 88 minutes/day. The playtime duration used for children under 15 was also used for people aged 16 to 20 years due to lack of playtime duration information for this age range and as a conservative assumption that can be further refined should risk be identified in the risk characterization stage of this assessment, see Section 4 of the *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h).

Synthetic leather clothing use patterns are represented by the high-, medium-, and low-intensity use scenarios in the clothing dermal exposure scenario. Less frequently used clothing items or clothing items that are not in direct skin contact as synthetic leather clothing can be (pants and tops), such as raincoats and mittens, are captured in the medium- and low-intensity use in the clothing scenario and the small articles with potential for semi-routine contact exposure scenario. In addition to the scenarios for dermal

exposure to DEHP from specific articles, a scenario was modeled in which consumers may have semi-routine contact with one or more small items containing DEHP. A complete list of articles and associated COUs modeled under this scenario is outlined in Section 2.3.1. Although dermal contact with individual items is expected to be short and/or irregular in occurrence, use of these articles is not well documented, and there is likely to be significant variability in use patterns between individual consumers. However, given the number and variety of small items identified with DEHP content, EPA considers it reasonable to assume that an individual could have significant daily contact with some combination of these items and/or with other similar items that have not been measured during monitoring campaigns. As such, articles modeled under this scenario were assumed to have dermal contact times of 120, 60, and 30 minutes per day.

Frequency of Use

For liquid and paste products modeled in CEM, frequency of contact was assumed to be equal to the frequency of use (per year and per day) that was applied in CEM modeling. For auto repair putty and inductance loop sealant, given the relatively niche use of the products, neither is expected to be used routinely. For both products, it was assumed that the product might be used for a single project once per year, which may take 2 days to complete. The frequency of use input is used in the calculation of acute and chronic exposure durations. Acute exposures are for an exposure duration of 1 day and chronic exposures are for an exposure duration of 1 year.

For articles, assumptions about frequency of use were made based on professional judgment using one contact per event duration as a conservative screening approach. Further refinement was considered at the risk calculation stage; see *Risk Evaluation for Diethylhexyl Phthalate (DEHP)* (U.S. EPA, 2025h). For articles that are expected to be used on a routine basis, such as children's toys, indoor furniture, shower curtains, rubber erasers, and adult toys, use was assumed to be once per day, every day, and recognizing that for adult toys daily use may be an upper bound or overestimation. For articles used in large home DIY projects (*e.g.*, wallpaper installation), due to significant work required to prepare and clean-up afterwards, it was assumed that these projects were conducted over a single day once per year. DEHP is expected to be present in polyurethane leather and waterproof garments such as raincoats and boots. These garments are not expected to be worn daily but could reasonably be worn on a routine basis. As such, dermal contact with clothing was modeled as one wear every week. Similarly, car mats were modeled as a single use each week, to represent an individual who does a weekly car cleaning or uses their vehicle awning for outdoor activities on a weekly basis. Air beds were modeled to be used sporadically for overnight trips and camping for an average of 3 nights once a month or 36 events in 1 year.

Table 2-11. Key Parameters Used in Dermal Models

Product	Scenario	Duration of Use (min)	Chronic Frequency of Use (year^{-1})	Acute Frequency of Use (day^{-1})	DEHP Flux [a] (mg/cm^2/h)	Contact Area
Adult toys	High	60	365	1	4.80E−05	Inside of two hands (palms, fingers)
	Medium	30				
	Low	15				
Air beds (screening flux-limited)	High	857	36	1	4.80E−05	25% of Face, hands, and arms
	Medium	480				25% of Face, hands, and arms
	Low	120				25% of Face, hands, and arms
Air beds (refined)	High	857	36	1	1.65E−05	25% of Face, hands, and arms
	Medium	480			6.00E−06	25% of Face, hands, and arms

Product	Scenario	Duration of Use (min)	Chronic Frequency of Use ($year^{-1}$)	Acute Frequency of Use (day^{-1})	DEHP Flux [a] ($mg/cm^2/h$)	Contact Area
	Low	120			1.63E−09	25% of Face, hands, and arms
Car mats	High	60	52	1	4.80E−05	10% of Hands (some fingers)
	Medium	30				
	Low	15				
Children's toys (legacy)	High	137	365	1	4.80E−05	Inside of two hands (palms, fingers)
	Medium	88				
	Low	24				
Children's toys (new)	High	137	365	1	4.80E−05	Inside of two hands (palms, fingers)
	Medium	88				
	Low	24				
Clothing	High	480	52	1	4.80E−05	50% of Entire body surface area
	Medium	240				25% of Face, hands, and arms
	Low	120				Both hands (entire surface area)
Erasers	High	60	365	1	4.80E−05	10% of Hands (some fingers)
	Medium	30				
	Low	15				
Furniture components (textile)	High	480	365	1	4.80E−05	50% of Entire body surface area
	Medium	240				25% of Face, hands, and arms
	Low	120				Inside of two hands (palms, fingers)
Insulated cords	High	60	365	1	4.80E−05	10% of hands (some fingers)
	Medium	30				
	Low	15				
Mobile phone covers	High	360	365	1	4.80E−05	Inside of one hand (palms, fingers)
	Medium	180				
	Low	90				
Shower curtains	High	60	365	1	4.80E−05	Inside of one hand (palms, fingers)
	Medium	30				
	Low	15				
Small articles with potential for semi-routine contact	High	120	365	1	4.80E−05	Inside of one hand (palms, fingers)
	Medium	60				
	Low	30				
Vinyl flooring	High	120	365	1	4.80E−05	Both hands (entire surface area)
	Medium	60				Inside of two hands (palms, fingers)
	Low	30				10% of Hands (some fingers)
Wallpaper (in place)	High	60	365	1	4.80E−05	Inside of one hand (palms, fingers)
	Medium	30				
	Low	15				
Wallpaper (installation)	High	480	1	1	4.80E−05	Inside of two hands (palms, fingers)
	Medium	240				

Product	Scenario	Duration of Use (min)	Chronic Frequency of Use (year^{-1})	Acute Frequency of Use (day^{-1})	DEHP Flux [a] (mg/cm^2/h)	Contact Area
	Low	120				
Auto care products	High	120	52	1	2.50E−05	10% of Hands (some fingers)
	Medium	60				
	Low	30				
Auto coatings	High	120	52	1	2.50E−05	10% of Hands (some fingers)
	Medium	60				
	Low	30				
Auto repair putty	High	120	2	1	2.50E−05	10% of Hands (some fingers)
	Medium	60				
	Low	30				
Concrete sealant	High	480	2	1	2.50E−05	Inside of two hands (palms, fingers)
	Medium	240				Inside of one hand (palms, fingers)
	Low	120				10% of Hands (some fingers)
Flooring adhesive	High	480	2	1	2.50E−05	10% of Hands (some fingers)
	Medium	240				
	Low	120				
Fragrance oil	High	120	52	1	2.50E−05	Inside of two hands (palms, fingers)
	Medium	60				
	Low	30				
Inductance loop sealant	High	480	365	1	2.50E−05	Inside of two hands (palms, fingers)
	Medium	240				Inside of one hand (palms, fingers)
	Low	120				10% of Hands (some fingers)

[a] See Section 2.3.1 and *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025c).

2.4 Key Parameters for Intermediate Exposures

The intermediate doses were calculated from the average daily dose (ADD in µg/kg-day) CEM output for that product using the same inputs summarized in Table 2-6 for inhalation and Table 2-9 for dermal. EPA used professional judgment based on manufacturer and online product use descriptions to estimate events per day and per month for the calculation of the intermediate dose (see Appendix 7A.3).

Table 2-12. Intermediate Event per Month and Day Inputs

Product	Events Per Day	Event Per Month
Flooring adhesives	1	2
Auto putties	1	2
Concrete sealant	1	2
Inductance loop sealant	1	2

2.5 Tire Crumb Rubber Modeling Approach

Tire crumb rubber was modeled using a similar approach to a previously published exposure characterization for the material (U.S. EPA, 2024). This approach models exposure to tire crumb via inhalation, ingestion, and dermal contact. It was peer reviewed at the time of publication and allows for an estimate of dose with the limited data available.

The exposure characterization provides concentrations of DEHP in air samples obtained from both outdoor (n = 25) and indoor playing fields (n = 15) and includes a separate document published in conjunction provided measurements of DEHP content in tire particles retrieved from the same locations (U.S. EPA, 2019b). These data were used to develop estimates for exposure to DEHP during sporting events on tire crumb fields as described below. All calculations are provided in the *DEHP Consumer Exposure Analysis* supplemental file (U.S. EPA, 2025c).

2.5.1 Tire Crumb Inhalation Exposure

Air samples were collected for SVOC analysis without a size-selective particle inlet to allow both vapor- and particle-phase SVOCs to be collected simultaneously. Separate particle- and gas-phase air concentrations were not measured. However, as previously discussed DEHP is more likely to be present in the particulate rather than gaseous phase. As such, it is unlikely that inhaled DEHP will be fully absorbed after inhalation and the fraction absorbed was estimated to be 0.7. This was the recommended value in the exposure characterization and likely represents a health-protective estimate given the slow rate of diffusion through solid media for DEHP and low solubility in aqueous fluids, which would limit partitioning to lung fluids. The inhaled dose per event is defined below:

Equation 2-9. Inhalation Dose Per Exposure Event

$$Inhalation\ Event\ Dose = (C_{air}\ x\ R_{inh}\ x\ ET\ x\ ABS)/BW$$

Where:

C_{air}	=	Concentration of DEHP in air (mg/m^3)
R_{inh}	=	Inhalation rate (m^3/h)
ET	=	Exposure time (hours)
ABS	=	Fraction absorbed (0.7)
BW	=	Body weight (kg)

Age-stratified inhalation rates during high-intensity activity were taken from Table 6-2 of the *Exposure Factors Handbook* (U.S. EPA, 2011c). Body weight values were the same as those used in CEM. Exposure time was assumed to be 1 hour for children aged less than 11 years, 3 hours for teens 11 to 16 years, and 2 hours for older teens and adults.

2.5.2 Tire Crumb Dermal Exposure

Dermal exposure to tire crumb was assessed under the assumption of dermal adherence during play and subsequent absorption. The 10th, 50th, and 90th percentile measurements of DEHP in tire crumb samples were used in low-, medium-, and high-exposure scenarios, respectively. The fraction of DEHP absorbed from each event was assumed to be 10 percent as recommended in the exposure characterization. It is likely that this value somewhat overestimates exposure given that uptake of DEHP is expected to be flux-limited. However, a flux-based value could not be calculated because (1) there were no data available to estimate total contact area of the particulate matter adhered to skin; and (2) the assumption of 10 percent absorption is expected to provide a reasonable, health-protective estimate. Dermal dose per exposure event was defined as follows:

Equation 2-10. Inhalation Dose Per Exposure Event

$$Dermal\ Event\ Dose = (C_{solid}\ x\ ADH\ x\ SA\ x\ ABS)/BW$$

Where:

C_{solid}	=	Concentration of DEHP in crumb rubber (mg/g)
ADH	=	Solids adherence on skin (g/cm^2 -day)
SA	=	Skin surface area available for contact (cm^2)
ABS	=	Fraction absorbed (0.1)
BW	=	Body weight (kg)

Age-specific adherence factors were calculated by estimating the percentage of a body part exposed while wearing a typical sports uniform during the summer, multiplying those percentages by the total surface area per body part found in EPA's *Exposure Factors Handbook* (U.S. EPA, 2011c), summing the products and then dividing by the total exposed surface area of the body parts to get a weighted adherence factor (Equation 5-4); this equation can be found in Chapter 7 of the Handbook (U.S. EPA, 2011b). Body part percentages exposed were assumed to be 100 percent of the face, 72.5 percent of the arms, 40 percent of the legs (to account for socks and short pants), and 100 percent of the hands. These values were recommended in the exposure characterization based on empirical observations.

Values for dermal adherence to skin were obtained from Kissel et al. (1996b). Only values for adherence of solids to skin after playing sporting events on tire crumb fields was used in this assessment; the upper- and lower-boundaries of the 95 percent confidence interval were used in high- and-low exposure scenarios, respectively. The geometric mean reported value was used in the medium-exposure scenario.

2.5.3 Tire Crumb Ingestion Exposure

The same values of DEHP content in solid particles described in Section 2.5.1 were used to estimate exposure by inadvertent ingestion during play. The absorption fraction of 50 percent recommended in the exposure characterization was used (U.S. EPA, 2024). Ingestion dose per exposure event was then calculated as follows:

Equation 2-11. Ingestion Dose Per Exposure Event

$$Ingestion\ Event\ Dose = (C_{solid}\ x\ R_{ing}\ x\ ET\ x\ ABS)/BW$$

Where:

C_{solid}	=	Concentration of DEHP in crumb rubber (mg/g)
R_{ing}	=	Ingestion rate (g/day)
ET	=	Exposure time (day)
ABS	=	Fraction absorbed (0.5)
BW	=	Body weight (kg)

Age-stratified ingestion rates were taken from Table 5-1 in the *Exposure Factors Handbook* (U.S. EPA, 2011c).

2.5.4 Tire Crumb Calculation of Acute and Chronic Doses

For all exposure routes, acute and chronic doses were calculated as follows:

Equation 2-12. Chronic Average Daily Dose (CADD)

$$CADD = (Event\ Dose\ x\ Events\ x\ \ EF)/T_A$$

Where:

EF	=	Exposure frequency (days/year)
Events	=	Number of exposure events per day ($days^{-1}$)
T_A	=	Averaging time (years)

Equation 2-13. Acute Dose Rate (ADR)

$$ADR = (Event\ Dose\ x\ Events\ x\ EF)/T_A$$

Where:

EF	=	Exposure frequency ($days^{-1}$)
Events	=	Number of exposure events per day ($days^{-1}$)
T_A	=	Averaging time (days)

For all exposure scenarios, the number of exposure events per day was assumed to be one. For chronic dose calculations, the averaging time was assumed to be 1 year for all scenarios, and the exposure frequency assigned was 78 days per year for children under age 11 years, 138 days per year for older children and teens under 16 years, and 138 days per year for older teens and adults. These values were recommended in the exposure characterization document based on empirical observations (U.S. EPA, 2024).

3 CONSUMER EXPOSURE MODELING RESULTS

This section summarizes the dose estimates from inhalation, ingestion, and dermal exposure to DEHP in consumer products and articles. Exposure via the inhalation route occurs from inhalation of DEHP gas-phase emissions or when DEHP partitions to suspended particulate from direct use or application or installation of products and articles. Exposure via the dermal route occurs from direct contact with products and articles. Exposure via ingestion depends on the product or article use patterns. It can occur via direct mouthing (*i.e.*, directly putting an article in mouth) or ingestion of suspended and/or settled dust when DEHP migrates from a product or article to dust or partitions from gas-phase to dust.

3.1 Acute Dose Rate Results, Conclusions, and Data Patterns

The *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) summarizes the low-, medium-, and high-acute dose rate results for all lifestages from CEM modeling for inhalation and ingestion exposures as well as computational modeling for all dermal exposures. Products and articles marked with a dash (–) did not have dose results because the product or article was not evaluated quantitatively. See Section 2.1, Table 2-2, and Table 2-3 for a presentation of qualitative assessments and rationale for not evaluating certain exposure routes. Dose results applicable to bystanders are highlighted. Bystanders are people that are not in direct use or application of a product but can be exposed to DEHP by proximity to the use of the product via inhalation of gas-phase emissions or suspended dust. Some product scenarios were assessed with children under 10 years of age as bystanders and children older than 11 years as users because the products were not targeted for use by children less than 10 years old. In instances where a lifestage could reasonably be either a product user or bystander, the user scenario inputs were selected, as proximity to the product during use would result in larger exposure doses as compared to a bystander. The main purpose of *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) is to summarize acute dose rate results, show which products or articles did not have a quantitative result, and which results are used for bystanders. Data patterns are illustrated in figures after the table and includes summary descriptions of the patterns by exposure route and population or lifestage.

Figure 3-1 through Figure 3-7 show acute dose rate data for all products and articles modeled in all lifestages. For each lifestage, figures are provided which show ADR estimated from exposure via inhalation, ingestion (aggregate of mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact. Inhalation exposure from toys, flooring, indoor furniture, wallpaper, shower curtains, wire insulation, air beds, and car mats include consideration of dust collected on the surface and settled dust of a relatively large area, like flooring and wallpaper, but also multiple toys and wires collecting dust with DEHP and subsequent inhalation and ingestion. Ingestion route acute dose results show the individual and sum of all ingestion scenarios (mouthing, suspended dust and surface dust). Among the younger lifestages, there was no clear pattern that showed a single exposure pathway most likely to drive exposure. However, for teens and adults, dermal contact was a slight driver of exposure to DEHP, with the dose received being generally higher than or similar to the dose received from exposure via inhalation or ingestion.

The spread of values estimated for each product or article reflects the aggregate effects of variability and uncertainty in key modeling parameters for each item; acute dose rate for some products/articles covers a larger range than others primarily due to a wider distribution of DEHP weight fraction values, chemical migration rates for mouthing exposures, and behavioral factors such as duration of use or contact time and mass of product used as described in Section 2.2.3. Key differences in exposures among lifestages include (1) designation as product user or bystander; (2) behavioral differences such as mouthing durations, hand to mouth contact times, and time spent on the floor; and (3) dermal contact expected from touching specific articles that may not be appropriate for some lifestages. Figures and

observations specific to each lifestage are provided below.

Across routes, ingestion of DEHP has the overall second highest doses. For articles assessed for mouthing, such as toys, furniture, wire insulation, and rubber erasers, exposure from mouthing is expected to have a larger impact on the overall ingestion dose. Mouthing tendencies decrease or cease entirely for children 6 to 10 years old. Thus, most scenarios do not estimate exposure via mouthing. Mouthing is still an important exposure route for adult toys for teenagers and adults who may use adult toys in such a manner during intimacy. Ingestion of settled dust is the only ingestion pathway for other products and articles other than adult toys, which suggests that indoor dust ingestion and inhalation are an important contributor to DEHP exposures.

Ingestion of DEHP via mouthing of legacy and new toys have similar high-intensity use doses because the same chemical migration rates were used for all scenarios. However, it is noteworthy that the concentration of DEHP in new toys is below the range of values used to derive the chemical migration rates; thus, it is possible that the high-intensity use mouthing exposure estimates are higher or lower than actual doses that would be received from these items. Articles that were not assessed for mouthing were assessed for ingestion of settled and suspended dust, in which the settled dust exposures tend to be larger than ingestion from suspended dust.

Inhalation of DEHP-contaminated dust is an important contributor to indoor exposures but was generally lower compared to the ingestion and dermal routes, with the highest inhalation ADR resulting from textiles used as furniture components. In some cases *(i.e.*, for adults), the ADR range is similar for auto coatings, auto repair putty, car mats, erasers, and wire insulation, because of similar contact patterns and frequencies, and from using the same dermal flux rates.

Infants, Toddlers, Preschoolers, and Middle Childhood (1–10 Years)
Acute exposure distributions (presented in Figure 3-1 through Figure 3-8) were relatively similar for products or articles and routes of exposure across these four lifestages. The highest ADR estimated for these lifestages was for dermal exposures to air beds, especially among infants.

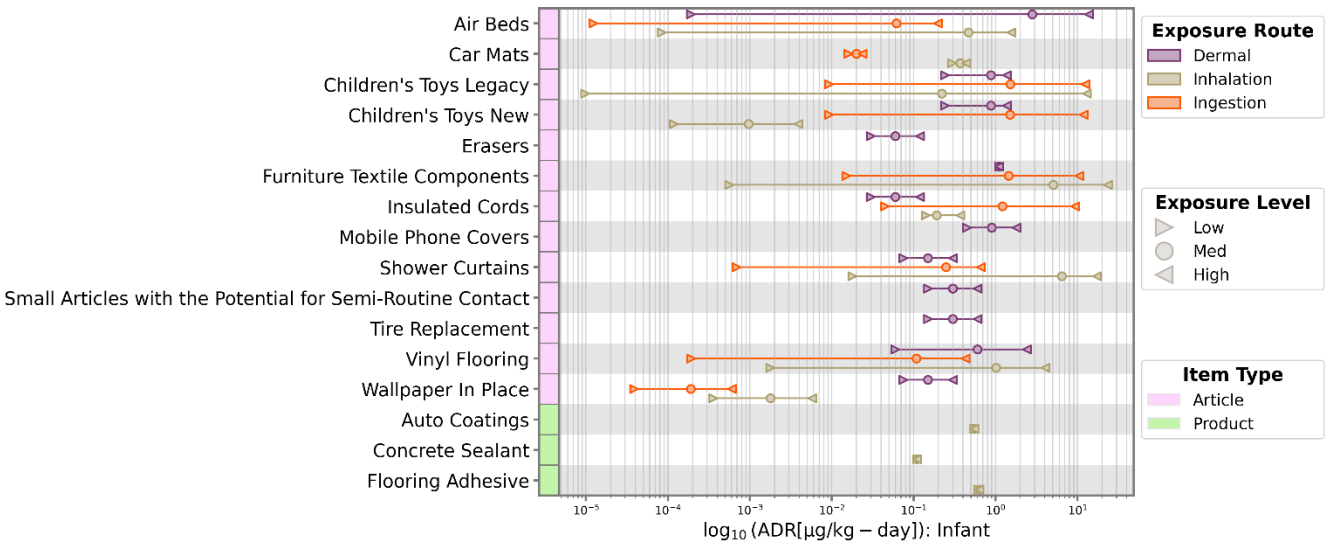

Figure 3-1. Acute Dose Rate for DEHP from Ingestion, Inhalation, Dermal Exposure Routes in Infants (<1 Year) and Toddlers (1–2 Years)

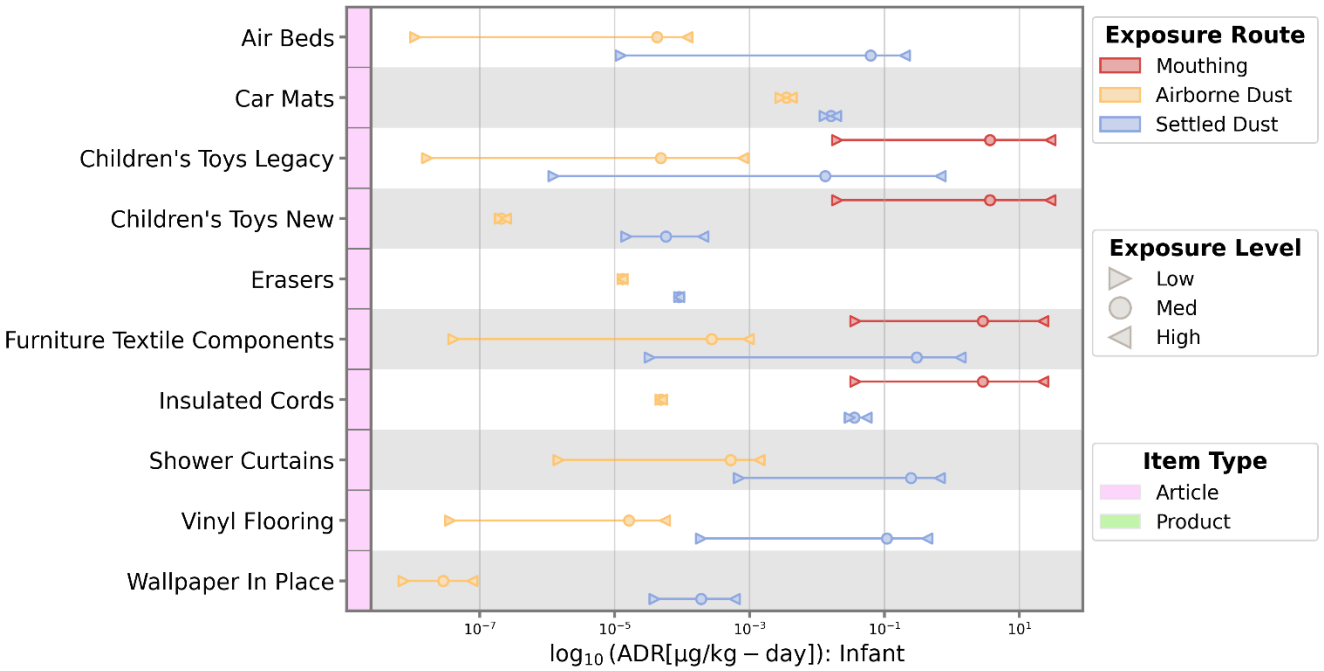

Figure 3-2. Acute Dose Rate for DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures in Infants (<1 Year) and Toddlers (1–2 Years)

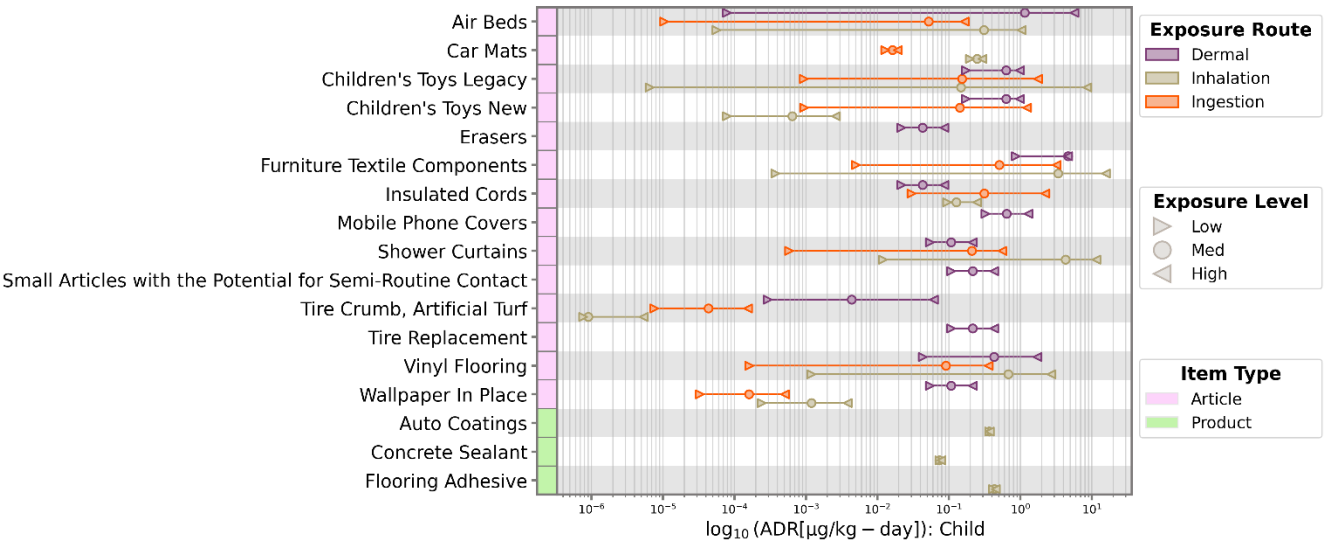

Figure 3-3. Acute Dose Rate for DEHP from Ingestion, Inhalation, and Dermal Exposure Routes in Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

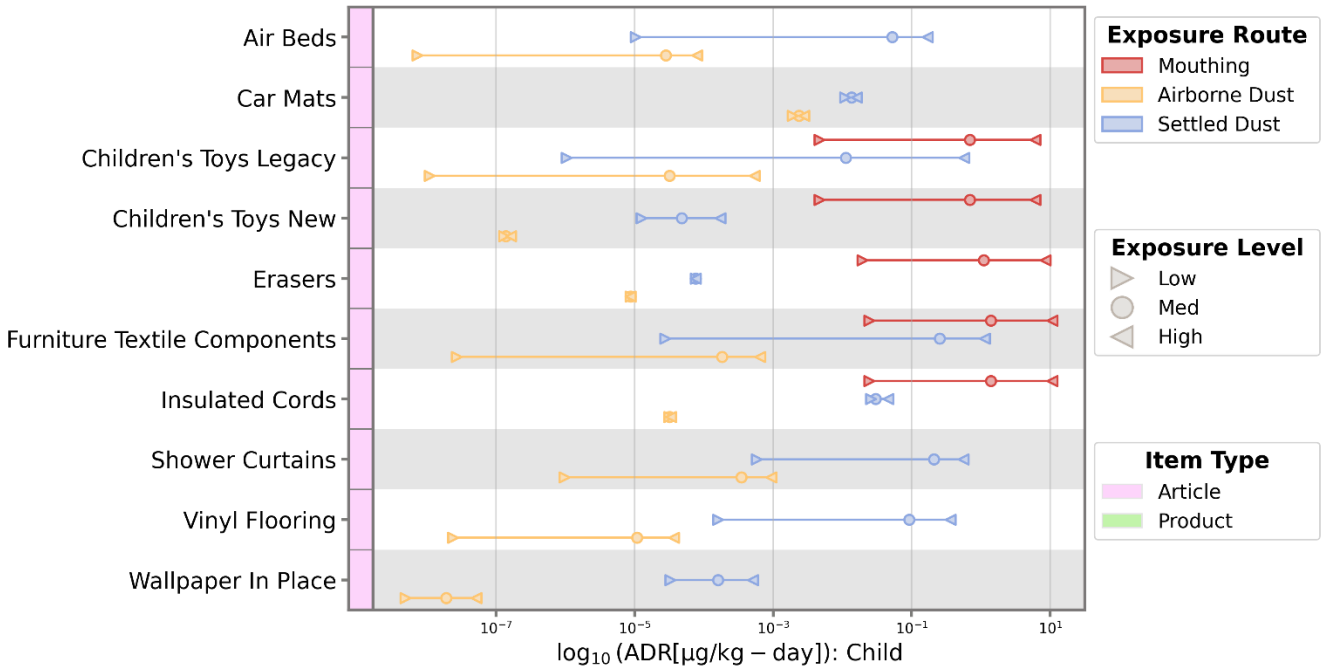

Figure 3-4. Acute Dose Rate for DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures in Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

Young Teens, Teenagers, Young Adults, and Adults (11 to 21 Years and 21+ Years)
Exposure patterns (presented in Figure 3-5 through Figure 3-8) were generally similar for all products and articles and across routes of exposure in these four lifestages, except that individuals 16 or older have added exposures to adult toys. The acute dose rate for some products/articles covers a larger range than others primarily due to a wider distribution of weight fraction values for those examples. Young adults (16- to 20-year-olds) can use these products in similar capacity as adults during DIY projects and as bystanders; thus, this lifestage was modeled as a user of the product rather than a bystander. Users have higher exposure doses when considering direct contact and use.

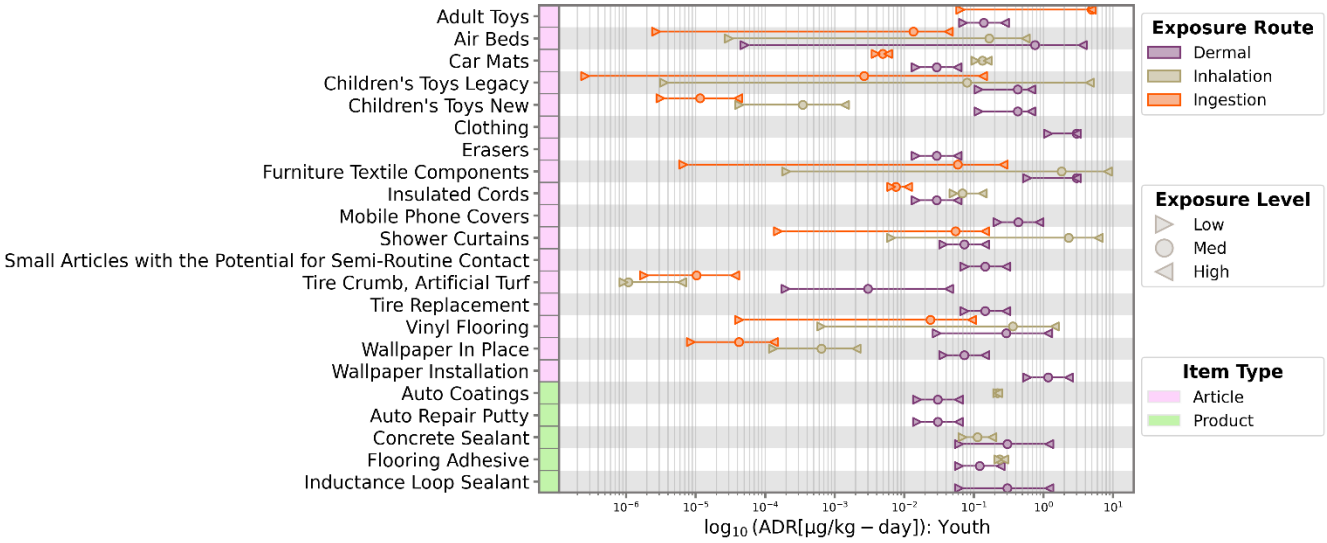

Figure 3-5. Acute Dose Rate of DEHP from Ingestion, Inhalation, and Dermal Exposure Routes for Youths (11–20 Years)

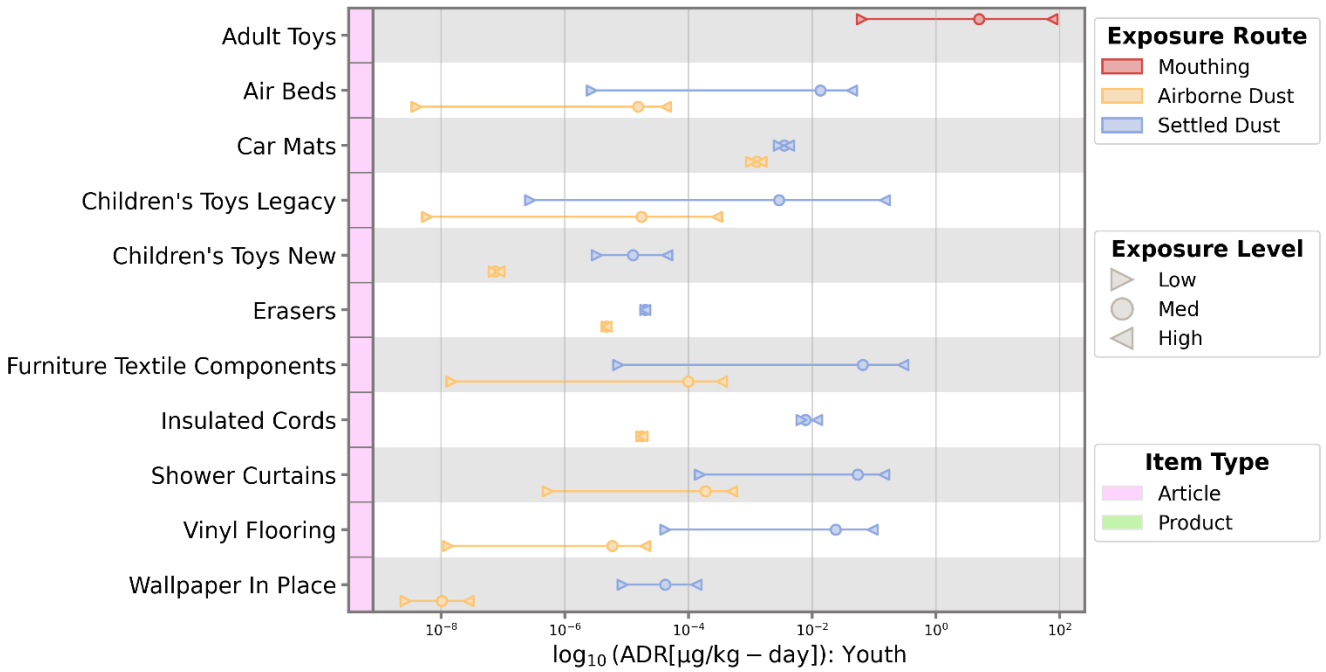

Figure 3-6. Acute Dose Rate of DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures for Youths (11–20 Years)

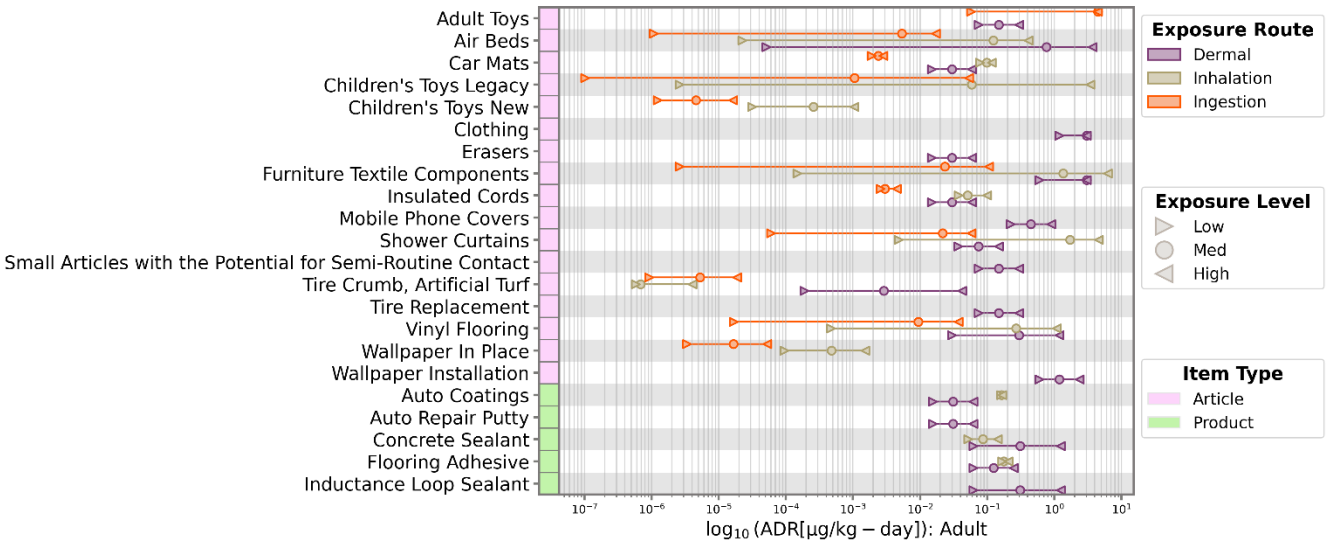

Figure 3-7. Acute Dose Rate of DEHP from Ingestion, Inhalation, and Dermal Exposure Routes in Adults (21+ Years)

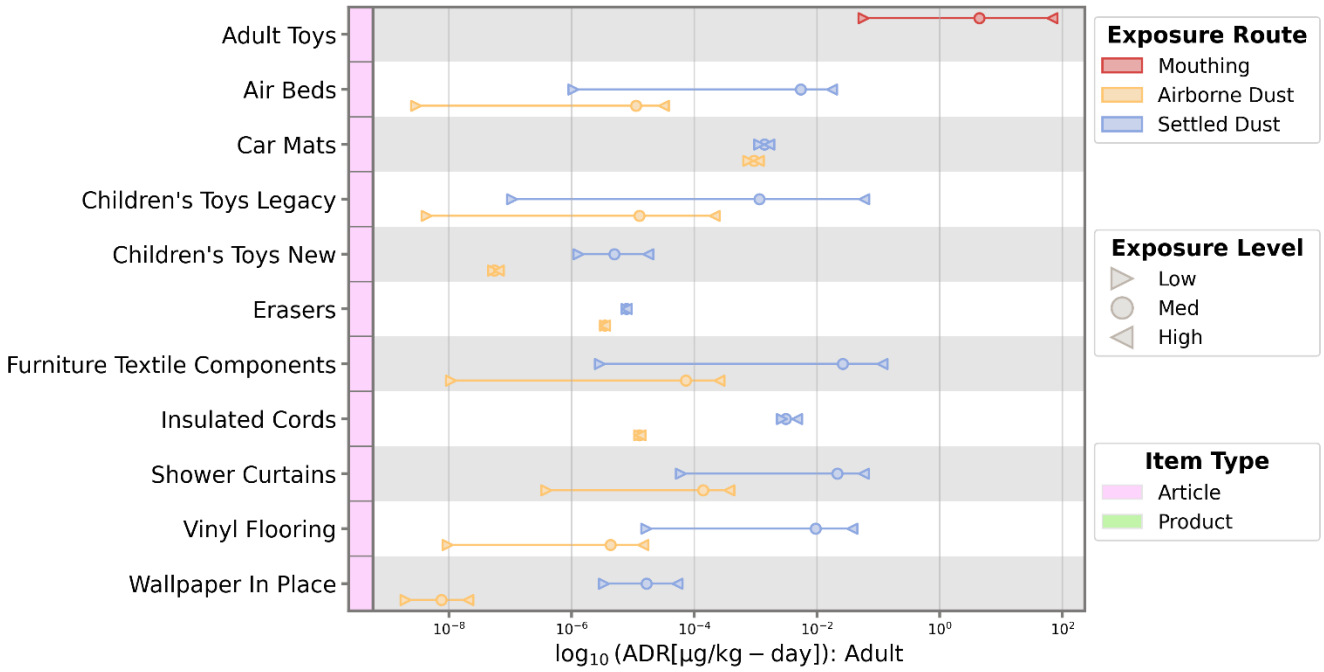

Figure 3-8. Acute Dose Rate of DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures in Adults (21+ Years)

3.2 Intermediate Average Daily Dose Conclusions and Data Patterns

The *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) summarizes the low-, medium-, and high-intensity intermediate average dose results from modeling in CEM and outside of CEM (dermal only) for all exposure routes and all lifestages. Only three product examples under the Construction, paint, electrical, and metal product adhesives and sealants COU were candidates for intermediate exposure scenarios. These products were identified as items that are likely used for short-term projects and, as a result, may lead to exposures that may take an extended period to complete (*i.e.*, 1–2 months) but are not expected to be used chronically (*i.e.*, for 1+ year). Intermediate exposure scenarios were built for products used as frequently as 30 to 60 days, and EPA assumed the products were used for used 30 days or approximately 1 month (for a detailed list of frequencies of use, see *Risk Evaluation for Diethylhexyl Phthalate (DEHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025d)). Some products did not have dose results because the product examples were not targeted for that lifestage for that exposure route. Scenarios without dose results are marked with a dash (–).

Only auto repair putty, concrete sealant, and flooring adhesive qualified to be used in intermediate scenarios. Based on manufacturer use description and professional judgment/assumption, these products may be used repeatedly within a 30-day period depending on projects. Infants to childhood lifestages do not have dermal doses as these products are not targeted for their use and application. However, starting from young teens through adults, it is possible that individuals from these lifestages could use auto repair putty and flooring adhesive in car or home renovation projects or in other hobbies. Infants to middle childhood lifestages are considered bystanders when these products are in use and are exposed via inhalation. Inhalation from flooring adhesives yielded a larger dose for infants across all routes and lifestages during application. This is likely due to infants being routinely relatively closer to the ground and therefore nearer to the application site. See Figure 3-9 through Figure 3-12 for intermediate dose visual representation. Intermediate exposures were not assessed for the ingestion route.

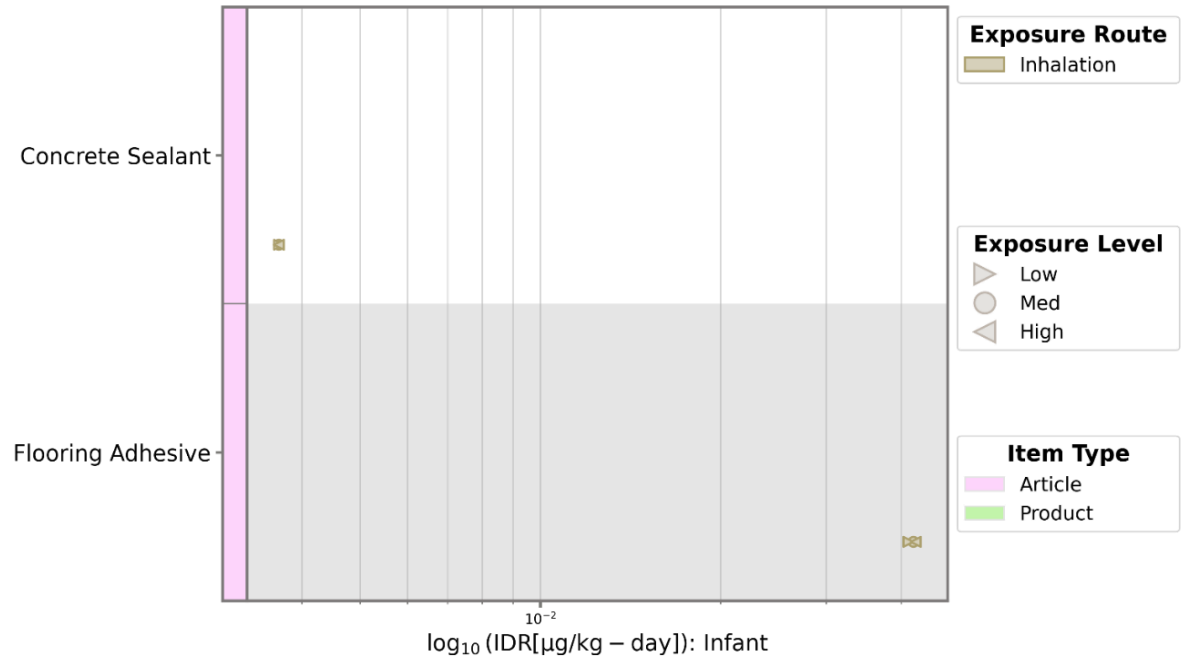

Figure 3-9. Intermediate Dose Rate for DEHP from Inhalation Exposure Route in Infants (<1 Year) and Toddlers (1–2 Years)

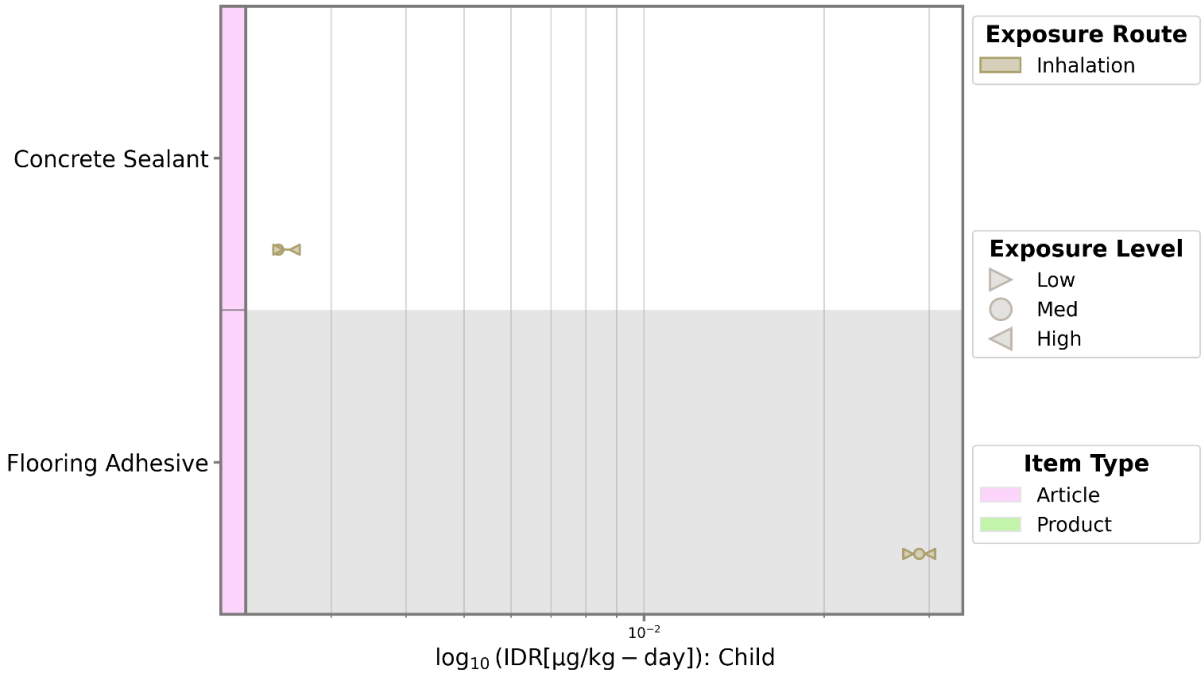

Figure 3-10. Intermediate Dose Rate for DEHP from Inhalation Exposure Route in Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

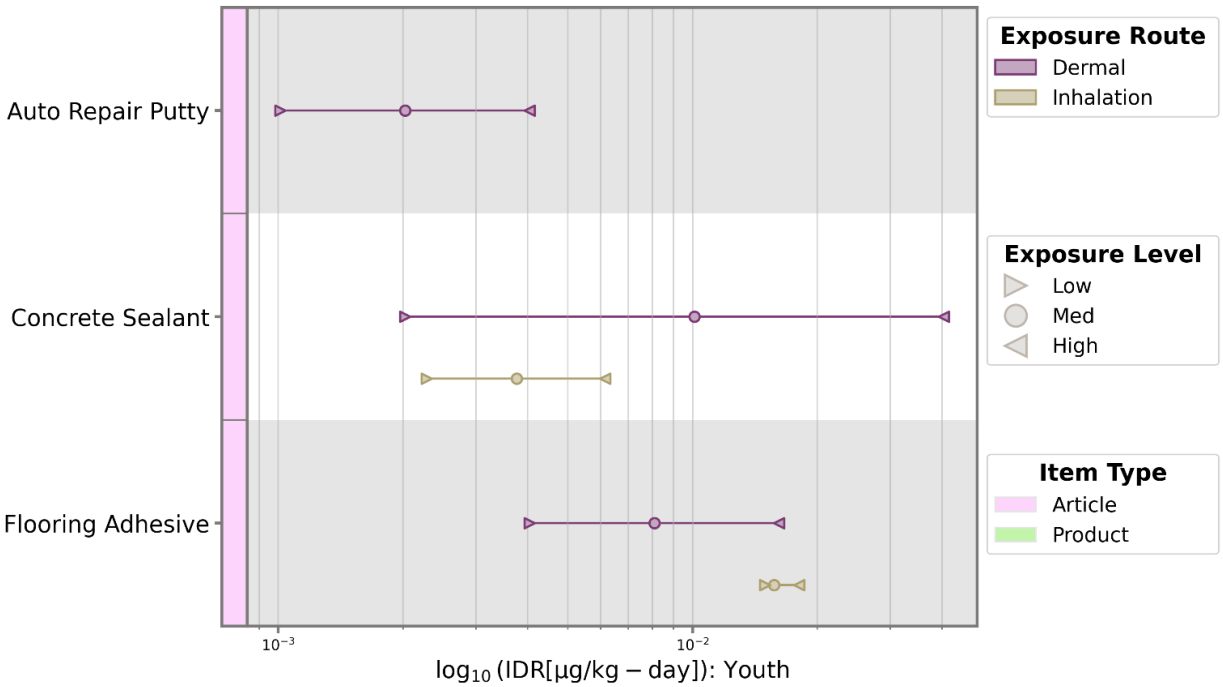

Figure 3-11. Intermediate Dose Rate for DEHP from Inhalation Exposure Route in Youths (11– 20 Years)

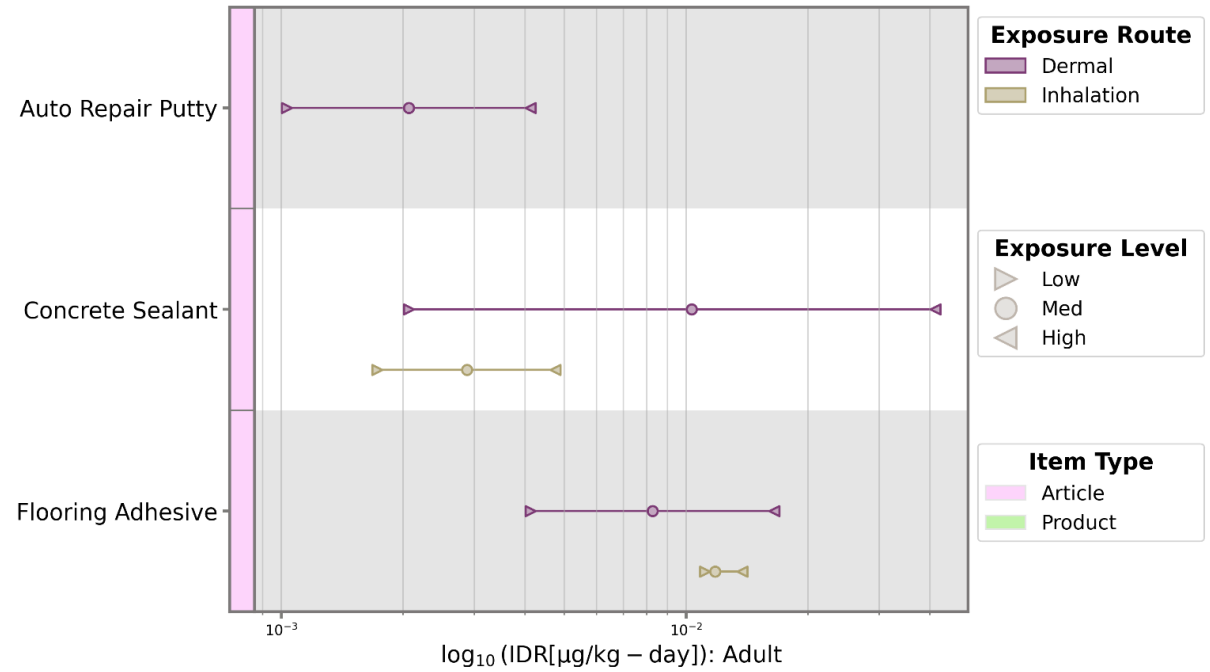

Figure 3-12. Intermediate Dose Rate for DEHP from Inhalation Exposure Route in Adults (21+ Years)

3.3 Non-Cancer Chronic Dose Results, Conclusions, and Data Patterns

The *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) summarizes all the low-, medium-, and high-intensity chronic daily dose results from modeling in CEM and outside of CEM (dermal only) for all

exposure routes and all lifestages. Some products and articles did not have dose results because the product or article was not targeted for that lifestage or exposure route. Scenarios without dose results are marked with a dash (–). Doses resulting from product and article exposures are presented for users and bystanders. Bystanders are people that are not in direct use or application of the product/article but can be exposed to DEHP by proximity to the use of the product/article via inhalation of gas-phase emissions or suspended dust.

Some product scenarios were assessed with children under 10 years as bystanders, and children older than 11 years as users, because the products were not targeted for use by children less than 10 years old. People older than 11 years can also be bystanders; however, the user scenarios utilize inputs that would result in larger exposure doses. The main purpose of *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) is to summarize chronic daily dose results, show which products or articles did not have a quantitative result, and which results are used for bystanders. Data patterns are illustrated in figures after the table and includes summary descriptions of the patterns by exposure route and population or lifestage. The following set of figures (see Figure 3-13 through Figure 3-20) show chronic average daily dose data for all products and articles modeled in all lifestages. For each lifestage, figures are provided that show CADD estimated from exposure via inhalation, ingestion (aggregate and individual results for mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact. The chronic average daily dose (CADD) figures resulted in relatively similar overall data distribution as the acute doses.

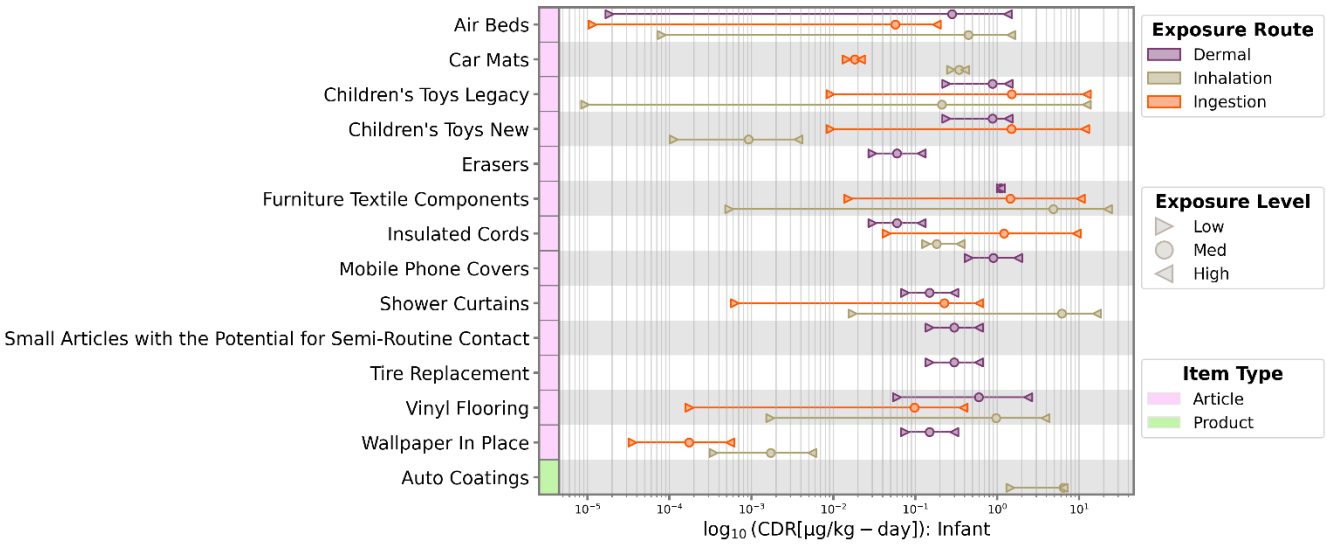

Figure 3-13. Chronic Dose Rate for DEHP from Ingestion, Inhalation, and Dermal Exposure Routes in Infants (<1 Year) and Toddlers (1–2 Years)

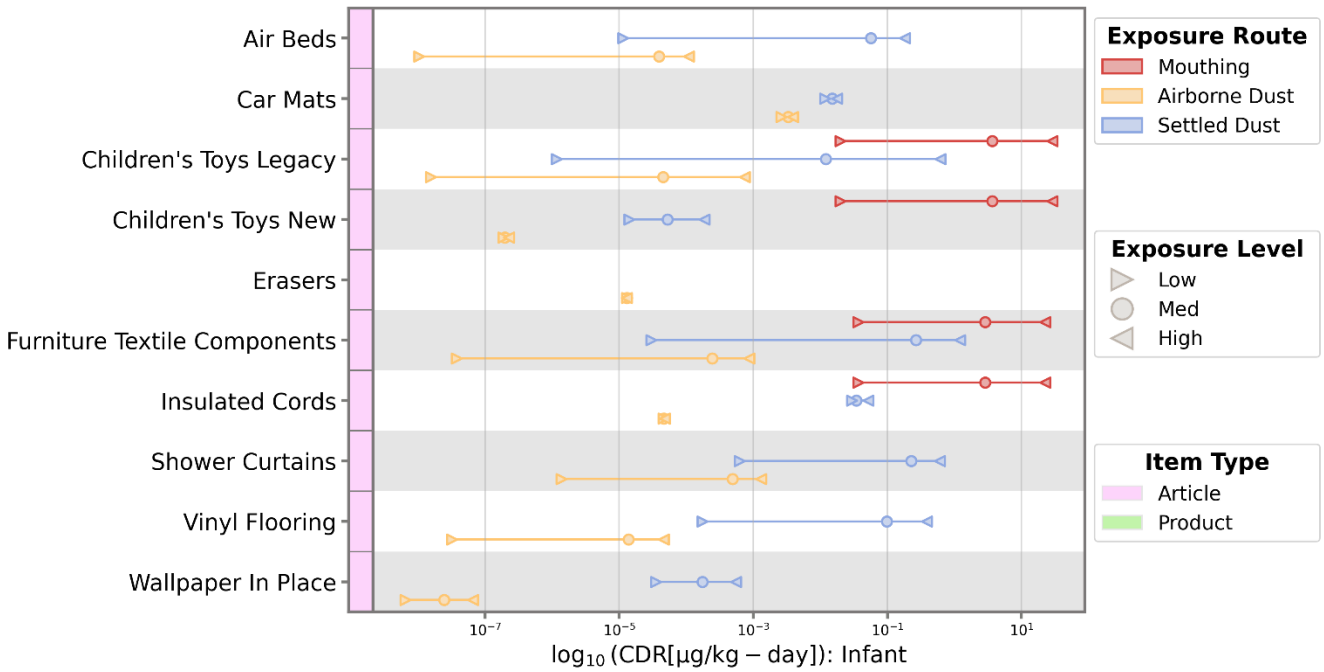

Figure 3-14. Chronic Dose Rate for DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures in Infants (<1 Year) and Toddlers (1–2 Years)

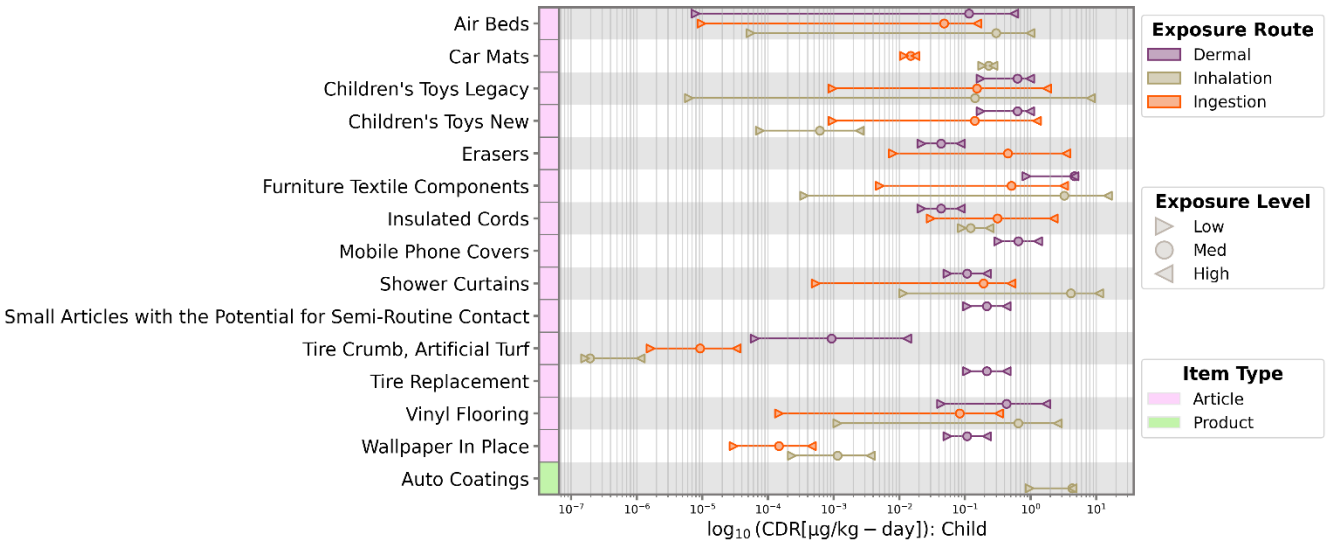

Figure 3-15. Chronic Dose Rate for DEHP from Ingestion, Inhalation, and Dermal Exposure Routes in Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

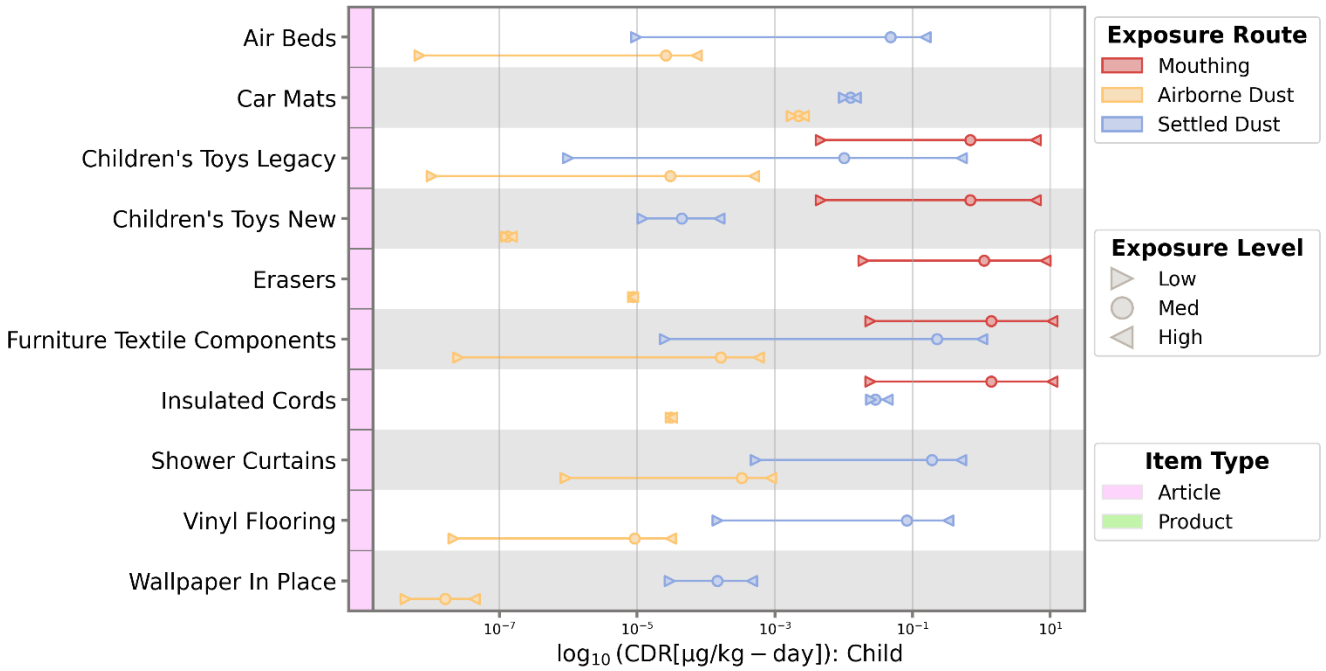

Figure 3-16. Chronic Dose Rate for DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures in Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

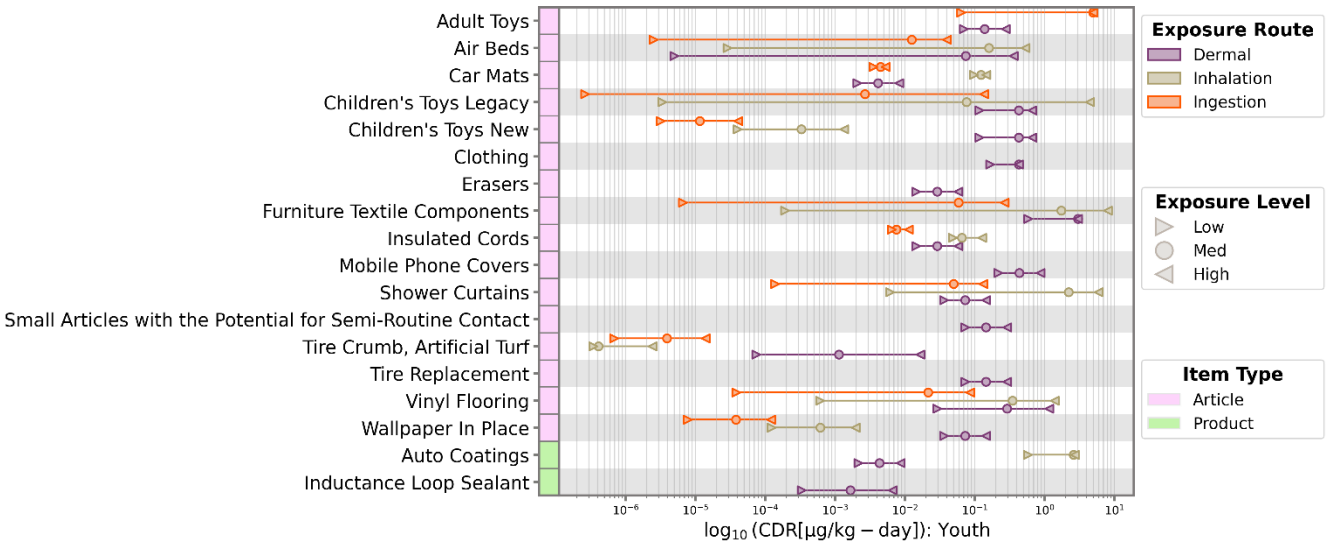

Figure 3-17. Chronic Dose Rate of DEHP from Ingestion, Inhalation, and Dermal Exposure Routes for Youths (11–20 Years)

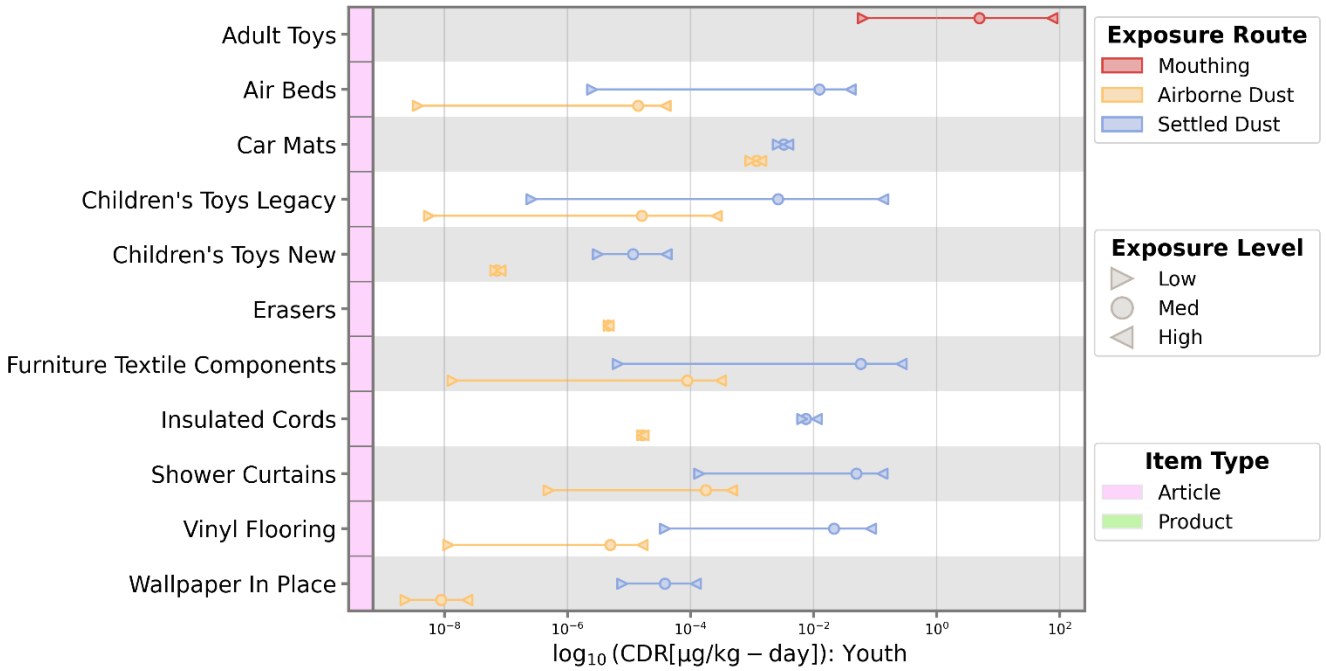

Figure 3-18. Chronic Dose Rate of DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures for Youths (11–20 Years)

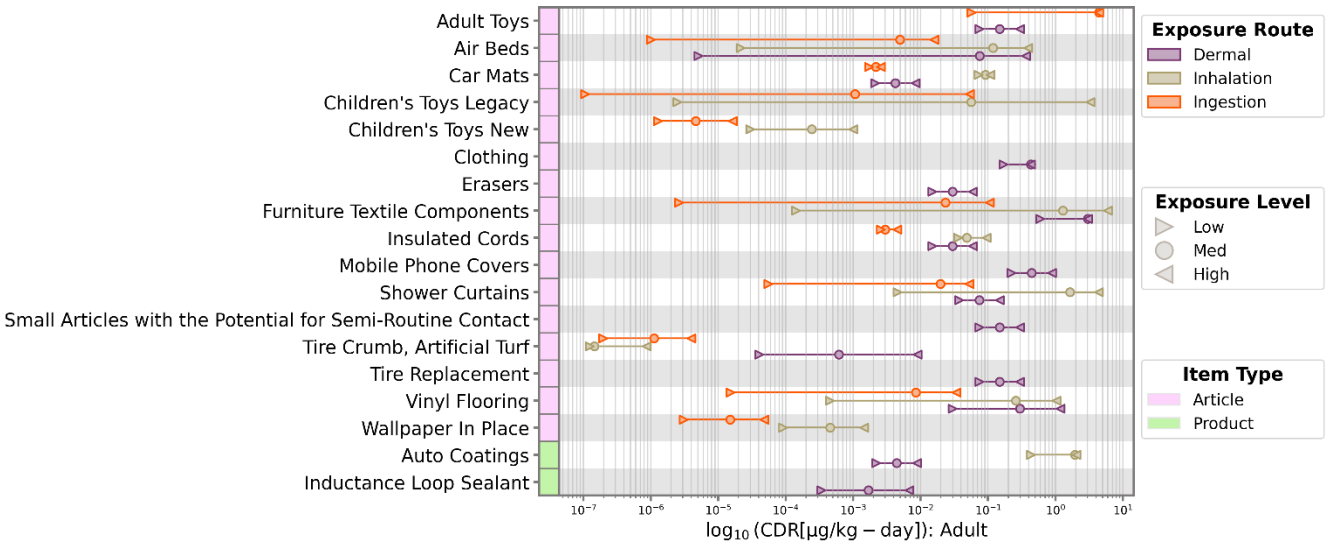

Figure 3-19. Chronic Dose Rate of DEHP from Ingestion, Inhalation, and Dermal Exposure Routes for Adults (21+ Years)

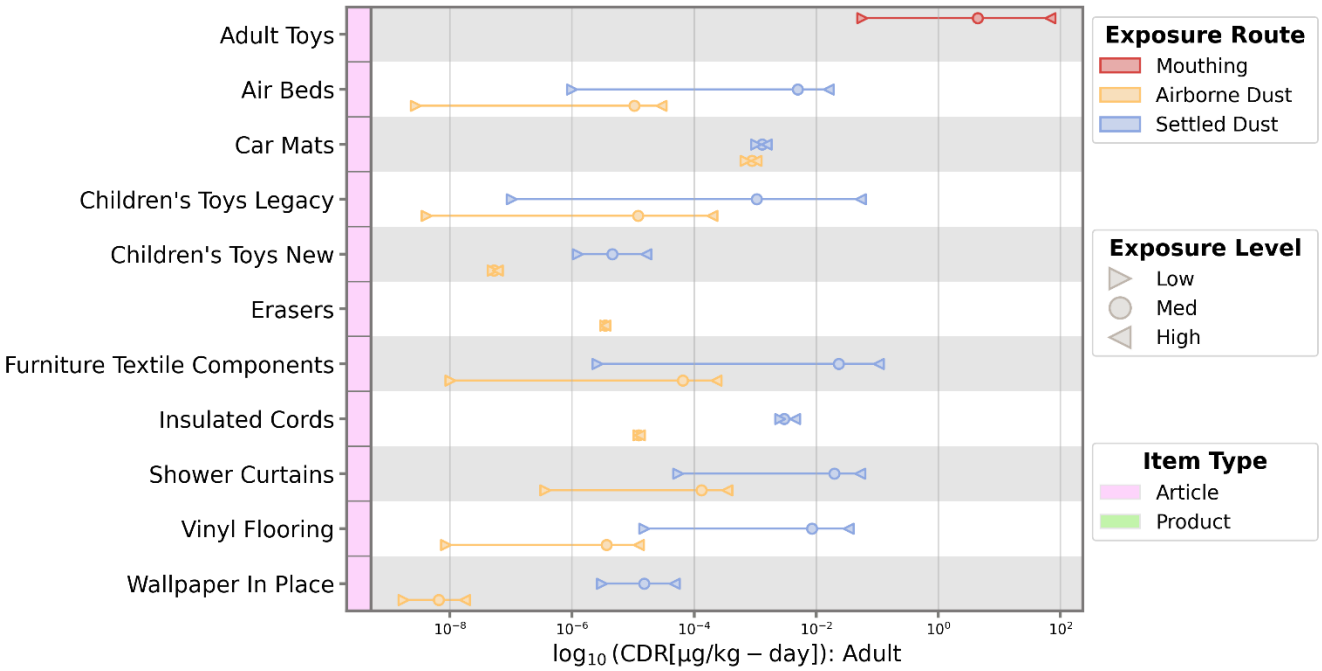

Figure 3-20. Chronic Dose Rate of DEHP from Mouthing, Suspended Dust, and Surface Dust Ingestion Exposures for Adults (21+ Years)

4 INDOOR DUST MODELING AND MONITORING COMPARISON

In this indoor dust exposure assessment, EPA compared modeling and monitoring data. Modeling data used in this comparison originated from the CEM articles inhalation and ingestion modeling approach in Section 2.2.2, and tire crumb rubber modeling approach in Sections 2.5.1 and 2.5.3. The goal of the indoor dust assessment was to reconstruct major indoor sources of DEHP in dust and obtain COU and product specific exposure estimates for ingestion and inhalation of dust. Exposure to DEHP via ingestion of dust was assessed for all articles expected to contribute significantly to dust concentrations due to high surface area (exceeding ≈1 m^2) for either a single article or collection of like articles, as appropriate. These included the following:

- car mats,
- vinyl flooring,
- wallpaper in-place,
- insulated cords,
- furniture components (textiles),
- air beds,
- shower curtains, and
- children's toys new and legacy.

These exposure scenarios were modeled in CEM for inhalation, ingestion of suspended dust, and ingestion of dust from surfaces. See Section 2.2.3 for CEM parameterization, input values, and article-specific scenario assumptions and sources for the DEHP indoor dust exposure analysis. The *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e) summarizes estimated risks from ingestion of settled dust doses used in this comparison. Other non-residential environments can have these articles, such as daycares, offices, malls, schools, car interiors, and other public indoor spaces. The indoor consumer articles exposure scenarios were modeled with stay-at-home parameters that consider use patterns similar to or higher than those in other indoor environments. Therefore, EPA concludes that exposures to similar articles in other indoor environments are included in the residential assessment, which represents a health-protective, upper-bound scenario.

The monitoring data considered are from residential dust samples from U.S.-based studies. Measured DEHP concentrations were compared to evaluate consistency among datasets. EPA used five U.S. monitoring studies to generate an estimate of overall DEHP exposure from ingestion of indoor dust and performed a monitoring and modeling comparison (Section 4.3). The monitoring studies and assumptions made to estimate exposure are described in Section 4.1.

4.1 Indoor Dust Monitoring

Ninety-seven studies were identified as containing measured DEHP concentrations in indoor dust during systematic review. Out of the 97 studies, 11 were identified as containing U.S. data on measured DEHP concentrations in dust in homes, offices, and other indoor environments. Out of the 11, 5 studies were selected because they collected settled indoor dust, which is used in the comparison to indoor dust ingestion modeling data (Section 4.3). The remaining 6 of 11 studies not used in the comparison with modeling data did not present original data and/or were not conducted in the Unites States. Data from other countries were not included in the comparison because of the expected difference in use patterns, behaviors, and residential characteristics as compared to the U.S. population. The studies that contained residential DEHP dust monitoring data were compared. Evaluating the sampled population and sampling methods across studies was important to determine whether the residential monitoring data were conducted on broadly representative populations (*i.e.*, not focused on a particular subpopulation).

In Rudel et al. (2001), six settled dust samples were collected from the United States. One sample was from an office and five samples were from three different homes in the living areas, attic, and basement. The study does not report the year of the samples taken. The samples were collected by slowly and lightly drawing the crevice tool just above the surface of rugs, upholstery, wood floors, windowsills, ceiling fans, and furniture in each room.

In Dodson et al. (2015), 49 settled dust samples were collected from homes in California during 2006. Dust samples were collected by slowly dragging the crevice tool just above the surface of rugs, upholstery, wood floors, windowsills, ceiling fans, and furniture in the primary living areas of the home for approximately 30 minutes.

In Bi et al. (2015), 43 settled dust samples were collected from multiple indoor environments in Delaware during 2013. These included 7 apartments, 3 gyms, 4 commercial stores, 5 college student dormitories, 7 offices, 3 house garages, 10 houses, and 5 daycare centers. Dust samples were collected using a bagged vacuum cleaner through a suction tube.

In Bi et al. (2018), a 92 settled dust samples were collected from homes in Texas during 2014 and 2015. For settled dust, a modified vacuum cleaner was used, which was connected to a special aluminum nozzle holder to avoid contact between dust and plastic parts and limit potential contamination. Dust sampling was conducted mainly in children's rooms. Dust was collected from the floor surface and from objects within 30 cm above the floor.

In Hammel et al. (2019), 188 settled dust samples were collected from the living room and playroom of homes in North Carolina during 2014 through 2016. Families were instructed not to clean their homes, specifically mop or vacuum, for at least 2 days prior to the scheduled visit. For collection, the entire exposed floor area of the room in which a/the child spent the most time active and awake, typically a living room or playroom, was vacuumed. Families were instructed not to wash their child's hands for at least 1 hour prior to our home visit. During the visit, research staff collected a hand wipe sample from each child using pre-cleaned cotton twill wipes.

Table 4-1 reports summary statistics for DEHP content in settled dust from these indoor environments. EPA compiled data from multiple indoor environments such as homes, retail, offices, daycares, gyms, and combined indoor environments, which refers to multiple indoor environments including household living areas and an attic, basement, and office building. Statistics (*e.g.*, mean, median, etc.) were directly taken from each study, and when individual data were provided, EPA calculated the summary statistics. Sampling methods that use wipes and vacuums to collect samples from hands or other surfaces are categorized as settled dust and were used in the assessment of dust ingestion route in this indoor dust exposure assessment. Combined indoor environment mean and medians tend to be higher than individual environments. Combined indoor environments refers to multiple indoor environments including household living areas, and an attic, basement, and office building. The highest mean DEHP concentrations were measured in daycares (1,664 µg/g) and gyms (1,256 µg/g), with the lowest in residential garages (59 µg/g). Residential median values range from 255 to 446 µg/g.

Table 4-1. Detection and Quantification of DEHP in House Dust from Multiple Indoor Environments

Study	Indoor Environment	N	Mean (µg/g)	Median (µg/g)	Min (µg/g)	Max (µg/g)	SD (µg/g)	95th Percentile (µg/g)	Detection Frequency (%)
Rudel et al. (2001)	Combined [a]	6	315 [c]	NR [b]	69.4	524	153	NR	100
Dodson et al. (2015)	Home	49	NR [b]	140	50	800	NR	460 [b]	NR
Bi et al. (2015)	Combined	43	637	336	16	5,924	929	NR	100
	Apartment	7	255 [c]	204	150	572	146	NR	100
	Home	10	446 [c]	339	235	803	207	NR	100
	Home garage	3	59	59	16	91	60	NR	100
	Student dormitory	5	839	803	258	1,604	580	NR	100
	Gym	3	1,256	1,104	756	1,908	590	NR	100
	Office	7	359	339	178	538	139	NR	100
	Commercial stores	4	561	435	152	1,222	472	NR	100
	Daycare center	5	1,664	618	156	5,924	2,433	NR	100
Bi et al. (2018)	Home	91	293 [b]	155	<MDL	3,980	502	NR	NR [b]
		92	271 [b]	155	12.8	2120	347	NR	NR [b]
Hammel et al. (2019)	Home	188	NR	118.570	6.213	NR	NR	484.403	100

MDL = method detection limit; NR = not reported
[a] Combined refers to multiple indoor environments including household living areas, attic, basement, and an office building.
[b] Used in dust ingestion calculations for central tendency (mean) and high-end tendency (95th percentile), Equation 4-2.

The number of studies sampled, states, and samples among the studies provides a robust level of confidence in these data adequately representing the U.S. population. Additionally, the study with the largest number of samples, Hammel et al. (2019), provided generic descriptions of the articles that may be sources of DEHP in the indoor environment sampled. A comparison between modeled and monitoring data can provide some insight in the distribution and variability within monitoring and modeling estimates.

4.2 Indoor Dust Monitoring Approach and Results

To estimate DEHP dust ingestion, the central tendency ingestion weighted average is first calculated from the reported means and medians of measured concentrations for residential (homes and apartments) in Table 4-1 (note b). Studies that did not report means were not used in the calculation, and only residential settled dust concentration values were used to compare to modeling results (Section 4.2). The same equation was used to calculate the high-end tendency using the reported maximums and 95th percentile. The central tendency ingestion weighted average concentration is calculated using Equation 4-1.

Equation 4-1. Ingestion Weighted Average Concentration Calculation

$$DEHP\ Ingestion\ Weighted\ Average\ (\mu g/g\ DEHP) = \frac{Mean\ Ingestion\ Set\ 1\left(\frac{\mu g}{g}DEHP\right) \times Number\ in\ Set\ 1 \ldots + Mean\ Ingestion\ Set\ N\left(\frac{\mu g}{g}DEHP\right) \times Number\ in\ Set\ N}{Number\ in\ Set\ 1 \ldots + Number\ in\ Set\ N}$$

EPA used recent U.S. sources for dust ingestion rate and body weights from Özkaynak et al. (2022). In their study, Özkaynak et al. (2022) parameterized the Stochastic Human Exposure Dose Simulation (SHEDS) Model to estimate dust and soil ingestion for children ages 0 to 21 years old with U.S. data, including the Consolidated Human Activity Database (CHAD) diaries. This most recent version incorporates new data for young children including pacifier and blanket use, which is important because dust and soil ingestion is higher in young children relative to older children and adults due to pacifier and blanket use, increased hand-to-surface contact, and increased rates of hand-to-mouth activity. Geometric mean and 95th percentile dust ingestion rates for ages 0 to 21 years were taken from Özkaynak et al. (2022) to estimate DEHP ingestion doses in dust (Table 4-2). The geometric mean (GM) was used as the measure of central tendency because the distribution of doses is skewed as dust ingestion doses in young children (3 months to 2 years) are higher vs. older children and adults.

Body weights representative of the U.S. population were taken from Table 8-1 in the *Exposure Factors Handbook* (U.S. EPA, 2011b). DEHP ingestion via dust was calculated according to Equation 4-2 for two scenarios: central tendency (geometric mean [GM] dust ingestion, median DEHP concentration in dust) and high end (95th percentile dust ingestion, 95th percentile DEHP concentration in dust).

Equation 4-2. Calculation of DEHP Ingestion Dose

$$DEHP\ Ingestion\ Dose\ \left(\frac{\mu g\ DINP}{kg\ bw \times day}\right) = \frac{Dust\ ingestion\left(\frac{mg\ dust}{day}\right) \times Dust\ concentration\left(\frac{\mu g\ DEHP}{g\ dust}\right)}{kg\ bw} \times \frac{1\ g}{1000\ mg}$$

Özkaynak et al. (2022) did not estimate dust ingestion rates for ages beyond 21 years. However, the *Exposure Factors Handbook* does not differentiate dust or soil ingestion beyond 12 years old (U.S. EPA, 2017). Therefore, ingestion rates for 16 to 21 years, the highest age range estimated in Özkaynak et al. (2022), were used for ages beyond 21 years. Using body weight estimates from the *Exposure Factors Handbook*, estimates were calculated for DEHP ingestion dose for 21 to greater than 80 years (Table 4-3).

Estimates of DEHP ingestion in indoor dust per day based on monitoring data are presented in Table 4-2 and Table 4-3.

Table 4-2. Estimates of DEHP Dust Ingestion Per Day from Monitoring, Ages 0–21 Years

Age Range		0 to <1 Month	1 to <3 Months	3 to <6 Months	6 Months to <1 Year	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 to <16 Years	16 to <21 Years
Dust ingestion (mg/day) [a]	GM	19	21	23	26	23	14	15	13	8.8	3.5
	95th Percentile	103	116	112	133	119	83	94	87	78	46
Body weight (kg) [b]		4.8	4.8	5.9	7.4	9.2	11.4	13.8	18.6	31.8	56.8
DEHP Ingestion (µg/kg-day)	Central tendency (286 µg DEHP/g dust)	1.13	1.02	0.889	0.808	0.577	0.290	0.231	0.117	0.0443	0.0140
	High-end (479 µg DEHP/g dust)	1.90	1.71	1.49	1.35	0.967	0.486	0.387	0.196	0.0743	0.0234

[a] From Özkaynak et al. (2022)
[b] From U.S. EPA (2011b)

Table 4-3. Estimates of DEHP Dust Ingestion Per Day from Monitoring, Ages 21–80+ Years

Age Range		21 to <30 Years	30 to <40 Years	40 to <50 Years	50 to <60 Years	60 to <70 Years	70 to <80 Years	>80 Years
Dust ingestion (mg/day) [a]	GM	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	95th Percentile	46	46	46	46	46	46	46
DEHP Ingestion (µg/kg-day)	Central tendency (286 µg DEHP/g dust)	0.0128	0.0124	0.0120	0.0120	0.0121	0.0131	0.0146
	High-end (479 µg DEHP/g dust)	0.0214	0.0208	0.0201	0.0201	0.0203	0.0220	0.0245
Body weight (kg) [b]		78.4	80.8	83.6	83.4	82.6	76.4	68.5

[a] From Özkaynak et al. (2022) (rates for persons aged 16–21 years)
[b] From U.S. EPA (2011b)

4.3 Indoor Dust Comparison Between Monitoring and Modeling Ingestion Exposure Estimates

All indoor dust exposure scenarios were modeled in CEM for inhalation, ingestion of suspended dust, and ingestion of surface dust. The indoor assessment used CEM outputs for articles from the consumer analysis that have large surface area and hence potential to collect surface dust. See Section 2 for CEM parameterization, input values, and article specific scenario assumptions and sources. DEHP has a low volatility and partitions to particulate quickly while suspended particulate tends to settle and accumulate on surfaces. Exposure to DEHP via ingestion of suspended dust is expected to be lower than settled dust. Because monitoring dose rates were only assessed for settled dust ingestion, the comparison between monitoring and modeling only includes settled dust ingestion estimates for chronic daily doses. Estimates of the chronic daily dose of DEHP per type of consumer article for ingestion of settled dust are provided in the *DEHP Consumer Risk Calculator* (U.S. EPA, 2025e).

The exposure dose estimates for indoor dust from the CEM model are larger than those indicated by the monitoring approach. Table 4-4 compares the sum of the chronic dose central tendency for indoor dust ingestion from CEM outputs for all COUs to the central tendency predicted daily dose from the monitoring approach. EPA only considered articles that are present in residences and homes for comparison with monitoring data. Car mats, though present in indoor environments like vehicles, are not used in homes and therefore inclusion would not be appropriate. Air beds, while they can be present in homes, are not typically in-place like other articles that have a permanent presence in homes; thus, EPA did not include air beds in the sum of residential articles settled dust ingestion doses and comparison with monitoring data.

Table 4-4. Comparison Between Modeled and Monitored Daily Dust Dose Estimates for DEHP

Lifestage	Daily DEHP Dose Estimate from Dust, µg/kg-day, Modeled Exposure [a]	Daily DEHP Dose Estimate from Dust, µg/kg-day, Monitoring Exposure [b]	Margin of Error (Modeled ÷ Monitoring)
Infants (<1 Year) [c]	5.70E−01	9.8E−01	0.6
Toddlers (1–2 Years)	7.06E−01	5.8E−01	1.2
Preschoolers (3–5 Years)	7.97E−01	2.6E−01	3
Middle childhood (6–10 Years)	2.80E−01	1.2E−01	2
Young teens (11–15 Years)	1.57E−01	4.5E−02	3
Teenagers (16–20 Years)	1.24E−01	1.4E−02	9
Adults (21+ Years) [d]	5.60E−02	1.3E−02	4

[a] Sum of chronic doses for indoor dust ingestion for the "medium" dose scenario for all COUs modeled in CEM
[b] Central tendency estimate of daily dose for indoor dust ingestion from monitoring data
[c] Weighted average by month of monitored lifestages from birth to 12 months
[d] Weighted average by year of monitored lifestages from 21–80 years

The sum of DEHP doses from dust in CEM modeled scenarios were, in all but one (infant) case, higher than those predicted by the monitoring approach, see Table 4-4. This was expected as some input scenarios specifically considered high-end, though realistic, exposure scenarios that may not be captured in the monitoring data. These discrepancies partially stem from differences in the exposure assumptions of the CEM model vs. the assumptions made when estimating daily dust doses in Özkaynak et al. (2022). Dust doses in Özkaynak et al. (2022) decline rapidly as a person ages due to behavioral factors including walking upright instead of crawling, cessation of exploratory mouthing behavior, and reduced hand-to-mouth events. This age-mediated decline in dust dose, which is more rapid for the Özkaynak et

al. (2022) study than in CEM, partially explains why the margin of error between the modeled and monitoring results grows larger with age. Another source of the margin between the two approaches is the assumption that the sum of the indoor dust sources in the CEM modeled scenario is representative of items found in typical indoor residences. It is likely that individual residences have varying assortments and amounts of the products and articles that are sources of DEHP, resulting in lower and higher exposures. The article scenarios with the largest relative contributions to the total modeling aggregate is furniture components and shower curtains. These articles modeling scenarios may be using a larger surface area presence than the actual in U.S. homes and other indoor environments. Additionally, some of the monitoring data was collected prior to the 2008 and 2017 CPSIA phthalate rule which limits the content of certain phthalates to not exceed 0.1 percent. The monitoring data may contain articles that still contain higher levels of DEHP, are no longer present in U.S. homes, or have decreased significantly.

In the indoor dust modeling assessment, EPA reconstructed the scenario using consumer articles as the source of DEHP in dust. CEM modeling parameters and inputs for dust ingestion can partially explain the differences between modeling and monitoring estimates. For example, surface area, indoor environment volume, and ingestion rates by lifestage were selected to represent common use patterns. CEM calculates DEHP concentration in small particles (respirable particles) and large particles (dust) that are settled on the floor or surfaces. The model assumes these particles bound to DEHP are available via incidental dust ingestion and estimates exposure based on a daily dust ingestion rate and a fraction of the day that is spent in the zone with the DEHP-containing dust. The use of a weighted dust concentration can also introduce discrepancies between monitoring and modeling results. Additionally, the articles that are mainly driving the large difference, furniture components and shower curtains, may overestimate surface area presence in indoor environments. EPA determined that modeled and monitoring results were within an order of magnitude of one another. This observation further supports the approaches used in the modeling and monitoring indoor dust assessment.

5 WEIGHT OF SCIENTIFIC EVIDENCE

5.1 Consumer Exposure Analysis Weight of Scientific Evidence

Variability refers to the inherent heterogeneity or diversity of data in an assessment. It is a description of the range or spread of a set of values. Uncertainty refers to a lack of data or an incomplete understanding of the context of the risk evaluation decision. Variability cannot be reduced, but it can be better characterized while uncertainty can be reduced by collecting more or better data. Uncertainty is addressed qualitatively by including a discussion of factors such as data gaps and subjective decisions or instances where professional judgment was used. Uncertainties associated with approaches and data used in the evaluation of consumer exposures are described below.

The exposure assessment of chemicals from consumer products and articles has inherent challenges due to many sources of uncertainty in the analysis, including variations in product formulation, patterns of consumer use, frequency, duration, and application methods. Variability in environmental conditions may also alter physical and/or chemical behavior of the product or article. Key sources of uncertainty for evaluating exposure to DEHP in consumer goods and strategies to address those uncertainties are described in this section.

Generally, designation of robust confidence suggests thorough understanding of the scientific evidence and uncertainties. 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 exposure estimate. The designation of moderate confidence suggests some understanding of the scientific evidence and uncertainties. More specifically, the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure estimates. The designation of slight confidence is assigned when the weight of scientific evidence may not be adequate to characterize the scenario, and when there is an absence of complete information and there are additional uncertainties that may need to be considered.

Table 5-2 summarizes the overall uncertainty per COU and provides a discussion of rationale used to assign the overall uncertainty. The subsections preceding Table 5-2 describe sources of uncertainty for several parameters used in consumer exposure modeling that apply across COUs and provide an in depth understanding of sources of uncertainty and limitations and strengths within the analysis. The confidence to use the results for risk characterization ranges from moderate to robust. The basis for the moderate to robust confidence in the overall exposure estimates is a balance between using parameters that represent various populations, use patterns, and rely on protective assumptions that are not outliers, excessive, or unreasonable.

Product Formulation and Composition

Variability in the formulation of consumer products, including changes in ingredients, concentrations, and chemical forms, can introduce uncertainty in exposure assessments. In addition, data were sometimes limited for weight fractions of DEHP in consumer goods. EPA obtained DEHP weight fractions in various products and articles from MSDSs, databases, and existing literature (Section 2.2.3). Where possible, the Agency obtained multiple values for weight fractions for similar products or articles. The lowest value was used in the low-exposure scenario, the highest value in the high-exposure scenario, and the average of all values in the medium-exposure scenario. EPA decreased uncertainty in exposure and subsequent risk estimates in the low-, medium-, and high-intensity use scenarios by capturing the weight fraction variability and obtaining a better characterization of the products and articles varying composition within one COU. Overall weight fraction confidence is *moderate* for

products/articles with only one source and *robust* for products/articles with more than one source.

Product Use Patterns
Consumer use patterns like frequency of use, duration of use, and methods of application are expected to differ. Where possible, low-, medium-, and high-default values from CEM 3.2's prepopulated scenarios were selected for mass of product used, duration of use, and frequency of use. In instances where no prepopulated scenario was appropriate for a specific product, low, medium, and high values for each of these parameters were estimated based on the manufacturers' product descriptions. EPA decreased uncertainty by selecting use pattern inputs that represent product and article use descriptions and furthermore capture the range of possible use patterns in the high- to low-intensity use scenarios. Exposure and risk estimates are considered representative of product use patterns and well characterized. Most use patterns overall confidence is rated *robust*.

Article Surface Area
The surface area of an article directly affects the potential for DEHP emissions to the environment. For each article modeled for inhalation exposure, low, medium, and high estimates for surface area were calculated (Section 2.2.3). This approach relied on manufacturer-provided dimensions where possible, or values from the EPA *Exposure Factors Handbook* for floor and wall coverings. For small items which might be expected to be present in a home in significant quantities, such as insulated wires and children's toys, aggregate values were calculated for the cumulative surface area for each type of article in the indoor environment. Overall confidence in surface area is *moderate* for articles like wires because there is less understanding of the number of wires exposed to collect dust and the great variability that is expected may not be well represented. Overall confidence in surface area is *robust* for articles like furniture, wall coverings, flooring, toys, and shower curtains because there is a good understanding of the presence and dimensions in indoor environments.

Human Behavior
CEM 3.2 has three different activity patterns: stay-at-home, part-time out-of-the home (daycare, school, or work), and full-time out-of-the-home. The activity patterns were developed based on the CHAD diaries. For all products and articles modeled, the stay-at-home activity pattern was chosen as it is the most protective assumption.

Mouthing durations are a source of uncertainty in human behavior. The values for total daily mouthing durations used in this assessment are based on a study in which parents observed children (n = 236) ages 1 month to 5 years of age for 15 minutes each session and 20 sessions in total (Smith and Norris, 2003). There was considerable variability in the data due to behavioral differences among children of the same lifestage. For instance, while children aged 6 to 9 months had the highest average mouthing duration for toys at 39 minutes per day, the minimum duration was 0 minutes, and the maximum was 227 minutes per day. The observers noted that the items mouthed were made of plastic roughly 50 percent of the mouthing time, but this not limited to soft plastic items likely to contain significant plasticizer content.

Greene (2002) reported mouthing behaviors in 169 children aged up to 36 months, using professional observers who recorded mouthing activities over 4 hours (2 hours on 2 separate days). That study provided a more detailed breakdown of mouthing times by material type, specifically distinguishing between soft plastic and other materials. As shown in Table 5-1, the data indicate that among items classified as soft plastic toys, teethers, and rattles soft plastic items accounted for 15 to 21 percent of total mouthing time in 3- to 12-month-olds, 21 to 26 percent in 12- to 24-month-olds, and 30 to 41 percent in 24- to 36-month-olds.

Rather than using the daily mouthing times for soft plastic toys reported in Greene (2002), the values reported in Smith and Norris (2003) were adjusted to 41 percent of the total reported values. This approach was selected for several reasons. First, Smith and Norris (2003) provides data on a broader range of age groups known to engage in mouthing behaviors. In addition, Smith and Norris (2003) may provide more reliable estimates of total mouthing durations as they studied a larger sample size, evaluated observational data using multiple methods (parental observation, trained observers, and video recordings), and estimated total daily mouthing duration on a child-by-child basis from recorded waking and non-eating hours. Lastly, Greene (2002) used a model to estimate daily values, which introduces additional uncertainty.

Synthetic leather textiles present an additional uncertainty in estimating soft plastic mouthing durations, because these materials are unlikely to have been classified as soft plastic by observers, these materials may not be well captured by the data reported in Greene (2002). However, Smith and Norris (2003) reported that textiles accounted for up to 10 percent of total daily mouthing duration. Given that synthetic leather likely represents only a fraction of this category, the assumption that soft plastic items account for 41 percent of total mouthing time remains a health-protective approach. The approach used to estimate mouthing durations in this assessment leverages the strengths of both studies and is expected to provide reasonable estimates that reflect both total daily mouthing for each age group and the prevalence of soft plastic materials likely to contain phthalates in mouthed items.

Table 5-1. Article Mouthing Behaviors Among Children up to 36 Months

Category of Item Mouthed	Mouthing Durations (min/h) for 3- to 12-Month-Old Children		Mouthing Durations (min/h) for 12- to 24-Month-Old Children		Mouthing Durations (min/h) for 24- to 36-Month-Old Children	
	Mean	99th Percentile	Mean	99th Percentile	Mean	99th Percentile
Soft plastic toys, teethers, and rattlers	0.32	2.02	0.2	1.27	0.09	1.6
Toys, teethers and rattles not soft plastic	1.77	7.72	0.56	4.64	0.21	2.27
Percent of toys, teethers and rattles composed of soft plastic	15.3%	20.7%	26.3%	21.5%	30.0%	41.3%

Modeling Tool

Confidence in the model used considers whether the model has been peer reviewed and whether it is being applied in a manner appropriate to its design and objective. For example, the model used (CEM Version 3.2) has been peer reviewed, is publicly available, and has been applied in a manner intended by estimating exposures associated with uses of household products or articles. This modeling approach also considers the default values data source(s) such as building and room volumes, interzonal ventilation rates, and air exchange rates. Overall confidence in the proper use of CEM for consumer exposure modeling is *robust*.

Dermal Modeling for DEHP

Experimental dermal data was identified via the systematic review process to characterize consumer dermal exposures to liquids or mixtures and formulations containing DEHP (see Section 2.3.1). EPA has moderate understanding of the scientific evidence and the uncertainties and that the supporting scientific evidence against the uncertainties is reasonably adequate to characterize exposure estimates. The confidence in dermal exposure to liquid and solid products model used in this assessment is *moderate*.

EPA identified nine experimental studies directly related to the dermal absorption of DEHP. Of the nine, the Agency identified two studies that are most representative of DEHP exposure from consumer products and articles—one for liquid products (Hopf et al., 2014) and one for solid products (Chemical Manufacturers Association, 1991). Section 2.3.1 summarized the criteria applied to select these two studies.

The Chemical Manufacturers Association (1991) dermal absorption study was conducted *in vivo* using male F344 rats. There have been additional studies conducted to determine the difference in dermal absorption between rat skin and human skin. Specifically, Scott et al. (1987) examined the difference in dermal absorption between rat skin and human skin for four different phthalates (*i.e.*, dimethyl phthalate [DMP], diethylphthalate [DEP], dibutyl phthalate [DBP], and DEHP) using *in vitro* dermal absorption testing. Results from those experiments showed that rat skin was more permeable than human skin for all four phthalates. For example, rat skin was up to 30 times more permeable than human skin for DEP, and rat skin was up to 4 times more permeable than human skin for DEHP. Although there is uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP, EPA is confident that the *in vivo* dermal absorption data using male F344 rats provides an upper bound of dermal absorption of DEHP based on the findings of Scott et al. (1987).

On the other hand, Hopf et al. (2014) reported dermal absorption based on metabolically active excised human skin, within just a few hours after excision. However, it should be noted that there may have been an error with the reported applied dose. Based on supporting information reported in the study (*i.e.*, concentration of DEHP, application amount, and skin surface area), the Agency was able to recalculate the correct applied dose.

EPA used a screening flux-limited approach to assess dermal exposures to air beds. Upon examination of the dermal exposure results for air beds using the screening flux-limited approach, the Agency identified the concentration of DEHP in the article, direct surface contact area between skin and air bed and duration of contact, to be key drivers of risk estimates under the benchmark of 30 (see Section 2.3.2). Moreover, the screening flux-limited approach was independent of concentration due to an assumption of excess of DEHP available for exposure. This conservative assumption did not result in evidence of potential for risk for any products or articles other than air beds. Generally, the screening approach is assumed to represent conservative potential dermal exposure scenarios. To refine its assessment of dermal exposures to air beds, EPA considered the concentration of DEHP in air beds and a barrier bedsheet between air bed and skin to better estimate typical dermal exposures to air beds, based on a wide range of possible usage patterns. This refinement was based on the application of DEHP partitioning coefficients between the air bed, air between air bed, bedsheet, and skin—all of which were sourced from peer-reviewed literature (see Section 2.3.2). This increased EPA's confidence in the dermal exposure assessment of DEHP in air beds as it considers realistic exposure scenarios based on a wide range of possible usage patterns that consider long and shorter contact durations.

A key source of uncertainty regarding the dermal absorption of DEHP from products or formulations stems from the varying concentrations and co-formulants that exist in products or formulations containing DEHP. Dermal contact with products or formulations that have lower concentrations of DEHP may exhibit lower rates of flux because there is less material available for absorption. Conversely, co-formulants or materials within the products or formulations may lead to enhanced dermal absorption—even at lower concentrations. Therefore, it is uncertain whether the products or formulations containing DEHP would result in decreased or increased dermal absorption. Based on the available dermal absorption data for DEHP, EPA has made assumptions that result in exposure assessments that are human health-protective in nature.

Experimental dermal data were identified via the systematic review process to estimate dermal exposures to solid products or articles containing DEHP and a modeling approach was used to estimate exposures (see Appendix A.4). EPA has *moderate* confidence in the dermal exposure to solid products or articles modeling approach.

Modeling Parameters for DEHP Ingestion Via Mouthing

For chemical migration rates to saliva, existing data were highly variable both within and between studies. This indicates the significant level of uncertainty for the chemical migration rate, as it may also differ even among similar items due to variations in chemical makeup and polymer structure. As such, an effort was made to choose DEHP migration rates likely to be representative of broad classes of items that comprise consumer COUs produced with different manufacturing processes and material formulations. There is no consensus on the correct value to use for this parameter in past assessments of DEHP. The 2003 EU Risk Assessment for DEHP used a migration rate of 53.4 µg/cm^2/h selected from the highest individual estimate from a 1998 study by the Netherlands National Institute for Public Health and the Environment (RIVM) (ECJRC, 2003; Konemann, 1998). The RIVM study measured DEHP in saliva of 20 adult volunteers biting and sucking four PVC disks with a surface of 10 cm^2. Average migration to saliva from the samples tested were 8.4, 14, 4, and 9.6 µg/cm^2/h, with considerable variability in the results. The reported standard deviations were broad, up to twice the mean, for the three mouthing approaches (*i.e.*, mild, medium, and harsh mouthing scenarios), which highlights a lack of specificity in the associated data. In a more recent report, ECHA compiled and evaluated new evidence on human exposure to DEHP, including chemical migration rates (ECHA, 2013). They concluded that chemical migration rate of 14 µg/cm^2/h was likely to be representative of a "typical mouthing scenario" while a migration rate of 45 µg/cm^2/h was a reasonable worst-case estimate of this parameter. The "typical" value was determined by compiling *in vivo* migration rate data from existing studies (Niino et al., 2003; Sugita et al., 2003; Fiala et al., 2000; Meuling et al., 2000; Chen, 1998; Konemann, 1998). The "worst case" value was midway between the two highest individual measurements among all the studies (the higher of which was used in the 2003 EU risk assessment).

However, a major limitation of all existing data is that DEHP weight fractions for products tested in mouthing studies skew toward relatively high weight fractions (30–60%), and measurements for weight fractions less than 15 percent are rare in the dataset. Thus, it is unclear whether these migration rate values are applicable to consumer goods with low (<15%) weight fractions of DEHP, where rates might be lower than represented by typical or worst-case values determined by existing datasets. As such, based on available chemical migration rates of DEHP to saliva, the range of values used in this assessment (1.6, 13.3, and 44.8 µg/cm^2/h) are considered likely to capture the true value of the parameter depending on article expected uses. EPA assumes children's mouthing behavior can be harsh, medium, and mild for children's toys. Mouthing behavior for adults using adult toys is not expected to be harsh, which would likely result in the breakage of the article, and because adults tend to control the harshness of their mouthing better than infants and toddlers. EPA calculated a high-intensity use of adult toys using harsh mouthing approaches as part of the screening approach; however, recognizing that this is unlikely behavior, it was not further used in risk estimation efforts. The Agency did not identify use pattern information regarding adult toys and most inputs rely on professional judgment assumptions.

EPA has *moderate* confidence in mouthing estimates due to uncertainties about professional judgment inputs regarding mouthing durations for adult toys and synthetic leather furniture for children. There are also unknown uncertainties in using harsh mouthing approaches for the high-intensity use scenario for adult toys. In general, the chemical migration rate input parameter has a moderate confidence due to the large variability in the empirical data used in this assessment and unknown correlation between chemical

migration rate and DEHP concentration in articles.

Table 5-2. Weight of Scientific Evidence Summary Per Consumer COU

Consumer COU Category – Subcategory	Weight of Scientific Evidence	Overall Confidence
Automotive, fuel, agriculture, outdoor use products – Automotive care products; Lawn and garden care products	One scenario was assessed for this COU, garden hose. The overall confidence in this dermal exposure estimate is moderate for article exposures. There is generally some uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP. Although the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns.	Dermal – Moderate
Construction, paint, electrical, and metal products – Adhesives and sealants including one-component caulk, fillers and putties; Batteries; Construction and building materials covering large surface areas, including paper articles, metal articles, stone, plaster, cement, glass and ceramic articles; Electrical and electronic products (including as plasticizer); Paints and coatings	Ten different scenarios were assessed for this COU for products and articles with differing use patterns for which each scenario had varying number of identified product and article examples: adhesive/sealant for home DIY (large indoors, small outdoors), automotive filler/putty, batteries, vinyl flooring, wallpaper, small articles with the potential for semi-routine contact (phone charge, wireless earbuds, electrical tape), insulated cords, coating for home DIY (large outdoors), automotive coating. These scenarios capture variability in product formulation in the low-, medium-, and high-intensity use estimates. The overall confidence in this indoor COU inhalation and dust ingestion exposure estimate is robust because the CEM default parameters generally represent actual products on the market, relevant use patterns and location of use. The overall confidence in this dermal exposure estimate is moderate for article exposures. There is generally some uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP. Though, the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns. The overall confidence in this dermal exposure estimate is moderate for liquid product exposures. While Hopf et al. (2014) reported dermal absorption based on metabolically active excised human skin within just a few hours after excision, it should be noted that there may have been an error with the reported applied dose. Based on supporting information reported in the study (*i.e.*, concentration of DEHP, application amount, and skin surface area), EPA was able to recalculate the correct applied dose). Though the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns due to the reported uncertainty, the overall confidence was moderate.	Inhalation – Robust Dermal – Moderate
Furnishing, cleaning, treatment care products – Fabric, textile, and leather products, furniture and furnishings; Floor covering, construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles, fabrics, textiles, and apparel (as plasticizer)	Five different scenarios were assessed for this COU for products and articles with differing use patterns for which each scenario had varying number of identified article examples: synthetic leather furniture, synthetic leather clothing, small articles with the potential for semi-routine contact (outdoor furniture, children's bags, wallets, footwear, interior and exterior components of jackets, handbags), vinyl flooring, wallpaper. These scenarios capture variability in product formulation in the low-, medium-, and high-intensity use estimates. The overall confidence in this indoor COU inhalation and dust ingestion exposure estimate is robust because the CEM default parameters generally represent actual products on the market, relevant use patterns, and location of use. The overall confidence in this dermal exposure estimate is moderate for article exposures. There is	Inhalation and Dust Ingestion – Robust Mouthing – Moderate Dermal – Moderate

Consumer COU Category – Subcategory	Weight of Scientific Evidence	Overall Confidence
	generally some uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP, although the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns.	
Packaging, paper, plastic, toys, hobby products – Ink used for stamps; Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including paper articles, rubber articles, plastic articles (hard), plastic articles (soft) (as plasticizer); Toys, playground, and sporting equipment	Ten different scenarios were assessed for this COU for products and articles with differing use patterns for which each scenario had varying number of identified product and article examples: stamp ink, air mattresses and sleeping mats, rubber eraser, mobile phone covers, shower curtain, small articles with the potential for semi-routine contact (packaging, paper, plastic, toys, hobby products: cutting board, pencils, pouches, bags, hose, labels, covers, chewy toys, jewelry, gloves, packaging, mats, lampshade, vinyl floor runner, silly straws, stickers, diving goggles), children's toys (legacy, new), tire crumb, artificial turf, small articles with the potential for semi-routine contact (fitness balls, jump rope, yoga mat, football, and diving goggles). These scenarios capture variability in product formulation in the low-, medium-, and high-intensity use estimates. The overall confidence in this indoor COU inhalation and dust ingestion exposure estimate is robust because the CEM default parameters generally represent actual products on the market, relevant use patterns and location of use. The overall confidence in this dermal exposure estimate is moderate for article exposures. There is generally some uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP, although the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns. The overall confidence in this dermal exposure estimate is moderate for liquid product exposures. While Hopf et al. (2014) reported dermal absorption based on metabolically active excised human skin within just a few hours after excision, it should be noted that there may have been an error with the reported applied dose. Based on supporting information reported in the study (*i.e.*, concentration of DEHP, application amount, and skin surface area), EPA was able to recalculate the correct applied dose). Although the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns due to the reported uncertainty, the overall confidence was moderate.	Inhalation and Dust Ingestion – Robust Mouthing – Moderate Dermal – Moderate
Other – Novelty articles	One indoor scenario was assessed for this COU: adult toys. This scenario captures variability in article formulation in the low-, medium-, and high-intensity use estimates. EPA has *moderate* confidence in mouthing estimates due to uncertainties about professional judgment inputs regarding mouthing durations for adult toys. There are also unknown uncertainties in using harsh mouthing approaches for the high-intensity use scenario for adult toys. In general, the chemical migration rate input parameter has a moderate confidence due to the large variability in the empirical data used in this assessment and unknown correlation between chemical migration rate and DEHP concentration in articles The overall confidence in this dermal exposure estimate is moderate for article exposures. There is generally some uncertainty regarding the magnitude of difference between dermal absorption through rat	Mouthing – Moderate Dermal – Moderate

Consumer COU Category – Subcategory	Weight of Scientific Evidence	Overall Confidence
	skin vs. human skin for DEHP. Though, the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns.	
Other – Automotive articles	Two indoor scenarios were assessed for this COU, car mats and tire replacements. These scenarios capture variability in product formulation in the low-, medium-, and high-intensity use estimates. The overall confidence in this indoor COU inhalation and dust ingestion exposure estimate is robust because the CEM default parameters generally represent actual products on the market, relevant use patterns and location of use. The overall confidence in this dermal exposure estimate is moderate for article exposures. There is generally some uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DEHP. Although the default parameters applied for dermal absorption estimates generally represent actual products on the market and relevant use patterns	Inhalation and Ingestion – Robust Dermal – Moderate

5.2 Indoor Dust Monitoring Weight of Scientific Evidence

The weight of scientific evidence for the indoor dust exposure assessment of DEHP is dependent on studies that include indoor residential dust monitoring data Table 5-3. Only studies that included indoor dust samples were included for data extraction. In the case of DEHP, six studies collected settled indoor dust. Five of these studies contained data on residences in the United States and were selected for use in the indoor dust monitoring assessment as described in Section 4.1, as one study combined different indoor environments in the results and was not used in the analysis. The study ratings per the exposure systematic review criteria are also listed in Table 5-3.

Table 5-3. Weight of Scientific Evidence Conclusions for Indoor Dust Ingestion Exposure

Scenario	Studies Used in Monitoring Indoor Analysis	Systematic Review Rating	Confidence in Data Used	Confidence in Model Inputs		Weight of Scientific Evidence Conclusion
				Body Weight [a]	Dust Ingestion Rate [b]	
Indoor exposure to residential dust via ingestion	Dodson et al. (2015)	Medium	Moderate	Robust	Moderate	Moderate
	Bi et al. (2015)	High	Moderate			Moderate
	Bi et al. (2018)	High	Moderate			Moderate
	Hammel et al. (2019)	High	Robust			Robust
	Shin et al. (2019)	Medium	Moderate			Moderate

[a] U.S. EPA (2011b)
[b] Özkaynak et al. (2022)

Table 5-3 presents the level of confidence in the data quality of the input datasets for estimating dust ingestion from monitoring data, including the DEHP dust monitoring data themselves, the estimates of U.S. body weights, and the estimates of dust ingestion rates, according to the following rubric:

- Robust confidence means the supporting weight of scientific evidence outweighs the uncertainties to the point that EPA has decided that it is unlikely that the uncertainties could have a significant effect on the exposure estimate.
- Moderate confidence means the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure estimates, but uncertainties could have an effect on the exposure estimate.
- Slight confidence means there is an absence of complete information; there may be significant uncertainty in the underlying data that needs to be considered.

These confidence conclusions were derived from a combination of systematic review (*i.e.*, the quality determinations for individual studies) and professional judgment.

In Dodson et al. (2015) (systematic review rating of medium), monitoring data was collected in Richmond and Bolinas, California for DEHP from the California Household Exposure Study (CAHES) study conducted in 2006. This study sampled 49 nonsmoking households in a low-income urban community and a rural community around the San Francisco area. Samples were collected by slowly dragging a crevice tool just above the surface of rugs, upholstery, wood floors, windowsills, ceiling fans,

and furniture in the primary living areas of the home for approximately 30 minutes. Although these samples collect indoor dust samples from an existing study, the low income and rural population studied might not be representative of the general U.S. public. Because of this uncertainty, EPA has assigned moderate confidence to the use of this model input.

In Bi et al. (2015) (systematic review rating of high), monitoring data was collected from Dover, Delaware for DEHP in 2013. This study sampled 10 houses, with the floor material being made of carpet, hardwood, or a combination of both. Dust samples were collected using a bagged vacuum cleaner through an easily cleaned suction tube. Before each sampling, the internal surface of the suction tube was cleaned using an animal-hair brush and a piece of clean cloth, and a new bag was placed for dust collection. EPA believes these samples may adequately represent the general U.S. population, as the samples were collected in a recent time and were from homes in the United States. Because of this, the Agency has assigned moderate confidence to the use of this model input.

In Bi et al. (2018) (systematic review rating of high), monitoring data was collected from Texas for DEHP in 2014 and 2015. The study is part of a large project to investigate asthma triggers for children in low-income homes. A total of 54 homes (92 samples) from rural/semi-rural areas of central Texas enrolled in this study. Dust sampling was conducted mainly in children's rooms. Dust was collected from the floor surface and from objects within 30 cm above the floor. While these samples collect indoor dust samples from homes, the study selected low-income homes for children and is not representative of the general U.S. public. Because of this uncertainty, EPA has assigned moderate confidence to the use of this model input.

Monitoring data conducted in the United States was identified for DEHP from the Toddlers' Exposure to SVOCs in the Indoor Environment (TESIE) study conducted between 2014 and 2016 (Hammel et al., 2019) (systematic review rating of high). This study sampled 190 residences in Durham, North Carolina, and included vacuum dust sampling as well as hand wipes and urine samples. Households were selected from participants in the Newborn Epigenetics Study, which is a prospective pregnancy cohort that began in 2005 and recruited pregnant women who received services at Duke obstetrics facilities. Although these facilities are associated with a teaching hospital and university, services are not restricted to students, and the demographic characteristics of the TESIE study population match those of the surrounding Durham community (see Table 1 in Hammel et al. (2019)). Because this study carefully selected participants to avoid oversampling subpopulations and investigated a relatively large number of residences for a study of this type, and because EPA identified no reason to believe that households in the study location (Durham, North Carolina) would represent an outlier population that would not adequately represent the consumer practices of the broader U.S. public, EPA has assigned robust confidence to the use of this model input.

In Shin et al. (2019) (systematic review rating of medium), monitoring data was collected in Northern California from 2015 to 2016. This study sampled 38 family homes. From each household, one dust sample from an approximate 2 m^2 area in the main living room was collected using a high-volume small surface sampler (HVS3). Because this study did not provide much information about the households, it is hard to determine if they are representative of the general U.S. public. Because of this uncertainty, EPA has assigned moderate confidence to the use of this model input.

5.2.1 Assumptions in Estimating Doses from Indoor Dust Monitoring

5.2.1.1 Assumptions for Monitored DEHP Concentrations in Indoor Dust

The DEHP concentrations in indoor dust were derived from the five studies in Table 5-3. Three of the

studies rated moderate and two studies rated robust in confidence in data used. The studies rated moderate were determined to not be representative of a typical U.S. household, while the robust studies were assumed to be representative. The representativeness of each study was discussed in the previous section (Section 5.2). Samples were either taken from the living room or children's room, where the children's room was identified as the room in which the child(ren) residing in the home spent the most time. A key assumption made in this analysis is that dust concentrations in playrooms and living rooms are representative of those in the remainder of the home.

5.2.1.2 Assumptions for Body Weights

Body weights were taken from the *Exposure Factors Handbook* (U.S. EPA, 2011b), which were derived from CDC's National Health and Nutrition Examination Survey the (NHANES) 1999 through 2006 dataset. The NHANES studies were designed to obtain a nationally representative dataset for the United States and include weight adjustment for oversampling of certain groups (children, adolescents aged 12–19 years, persons 60+ years of age, low-income persons, African Americans, and Mexican Americans). Body weights were aggregated into the age ranges shown previously in Table 4-2 and Table 4-3.

5.2.1.3 Assumptions for Dust Ingestion Rates

To estimate daily dose of DEHP in residential indoor dust, a daily rate of dust ingestion is required. EPA used rates from Özkaynak et al. (2022), which modeled to estimate dust and soil doses for children from birth to 21 years of age. A probabilistic approach was used in the Özkaynak et al. (2022) study to assign exposure parameters including behavioral and biological variables. The exposure parameters are summarized in Table 5-4 and the statistical distributions chosen are reproduced in detail in the supplemental material for Özkaynak et al. (2022).

Table 5-4. Summary of Variables from Özkaynak et al. 2022 Dust/Soil Dose Model

Variable	Description	Units	Source
Bath_days_max	Maximum # days between baths/showers	days	Ozkaynak et al. (2011), based on Kissel 2003 (personal communication)
Dust_home_hard	Dust loading on hard floors	μg/cm^2	Adgate et al. (1995)
Dust_home_soft	Dust loading on carpet	μg/cm^2	Adgate et al. (1995)
F_remove_bath	Fraction of loading removed by bath or shower	(–)	Professional judgment
F_remove_hand_mouth	Fraction of hand loading removed by one mouthing event	(–)	Kissel et al. (1998) and Hubal et al. (2008)
F_remove_hand_wash	Fraction of hand loading removed by hand washing	(–)	Professional judgment
F_remove_hour	Fraction of dermal loading removed by passage of time	(–)	Ozkaynak et al. (2011)
F_transfer_dust_hands	Fraction of floor dust loading transferred to hands by contact	(–)	Ozkaynak et al. (2011)
F_transfer_object_mouth	Fraction transferred from hands to mouth	(–)	Zartarian et al. (2005), based on Leckie et al. (2000)
Hand_contact_ratio	Ratio of floor area contacted hourly to the hand surface area	1/h	Freeman et al. (2001)and Zartarian et al. (1997)
Hand_load_max	Maximum combined soil and dust loading on hands	μg/cm^2	Ozkaynak et al. (2011)
Hand_washes_per_day	Number of times per day the hands are	1/day	Zartarian et al. (2005)

Variable	Description	Units	Source
	washed		
Object_floor_dust_ratio	Relative loadings of object and floor dust after contact	(–)	Professional judgment, based on Gurunathan et al. (1998)
P_home_hard	Probability of being in part of home with hard floor	(–)	Ozkaynak et al. (2011)
P_home_soft	Probability of being in part of home with carpet	(–)	Ozkaynak et al. (2011)
Adherence_soil [a]	Accumulated mass of soil that is transferred onto skin	mg/cm^2	Zartarian et al. (2005), based on Holmes et al. (1999), Kissel et al. (1996a), and Kissel et al. (1996b)
Hand_mouth_fraction [a]	Fraction of hand area of one hand contacting the inside of the mouth	(–)	Tsou et al. (2017)
Hand_mouth_freq [a] (indoor/outdoor)	Frequency of hand-mouth contacts per hour while awake – separate rate for indoor/outdoor behavior	(–)	Black et al. (2005) and Xue et al. (2007)
Object_mouth_area [a]	Area of an object inserted into the mouth	cm^2	Leckie et al. (2000)
Object_mouth_freq [a]	Frequency at which objects are moved into the mouth	(–)	Xue et al. (2010)
P_blanket [b]	Probability of blanket use	(–)	Professional judgment
F_blanket [b]	Protective barrier factor of blanket when used	(–)	Professional judgment
Pacifier_size [b]	Area of pacifier surface	cm^2	Özkaynak et al. (2022)
Pacifier_frac_hard [b]	Fraction of pacifier drops onto hard surface	(–)	Professional judgment
Pacifier_frac_soft [b]	Fraction of pacifier drops onto soft surface	(–)	Professional judgment
Pacifier_transfer [b]	Fraction of dust transferred from floor to pacifier	(–)	Extrapolated from Rodes et al. (2001), Beamer et al. (2009), and Hubal et al. (2008)
Pacifier_washing [b]	Composite of the probability of cleaning the pacifier after it falls and efficiency of cleaning	(–)	Conservative assumption (zero cleaning is assumed)
Pacifier_drop [b]	Frequency of pacifier dropping	(–)	Tsou et al. (2015)
P_pacifier [b]	Probability of pacifier use	(–)	Tsou et al. (2015)

[a] Variable distributions differ by lifestage
[b] Variable only applies to children <2 years of age

5.2.2 Uncertainties in Estimating Doses from Monitoring Data

5.2.2.1 Uncertainties for Monitored DEHP Concentrations in Indoor Dust

For all five studies, there may be uncertainty for sampling biases including study location, household type (*i.e.*, only households that contain children) and self-selection of study participants. For example, Hammel et al. (2019) sampled residential house dust in 190 households in Durham, North Carolina, from a population selected from an existing pregnancy cohort study. In addition, differences in consumer behaviors, housing type and quality, tidiness, and other variables that affect DEHP concentrations in household dust are possible between participating households and the general

population.

5.2.2.2 Uncertainties for Body Weights

Body weights were obtained from the *Exposure Factors Handbook* (U.S. EPA, 2017), which contains data from the 1999 to 2006 NHANES. Body weights were aggregated across lifestages and averaged by sex. In general, body weights have increased in the United States since 2006 (CDC, 2013), which may lead to an underestimate of body weight in this analysis. This would lead to an overestimate of DEHP dose per unit body weight, because actual body weights in the U.S. population may be larger than those assumed in this analysis.

5.2.2.3 Uncertainties for Dust Ingestion Rates

Dust ingestion rates were obtained from Özkaynak et al. (2022) which uses mechanistic methods (the SHEDS Model) to estimate dust ingestion using a range of parameters (Table 5-4). Each of these parameters is subject to uncertainty, especially those which are derived primarily from the professional judgment of the authors. Because of the wide range of parameters and the lack of comparator data against which to judge, EPA is unable to determine the direction of potential bias in each of the parameters individually. For dust ingestion rates overall, the rates derived from Özkaynak et al. (2022) can be compared to those found in the *Exposure Factors Handbook* (U.S. EPA, 2017) (Table 5-5).

Table 5-5. Comparison Between Özkaynak et al. 2022 and EPA's *Exposure Factors Handbook* Dust Ingestion Rates

Age Range		0 to <1 Month	1 to <3 Months	3 to <6 Months	6 Months to <1 Year	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 to 16 Years	16 to <21 Years
Central tendency dust ingestion (mg/day)	Özkaynak et al. (2022)	19	21	23	26	23	14	15	13	8.8	3.5
	U.S. EPA (2017)	20	20	20	20	50	30	30	30	20 [a]	20

[a] The intake for an 11-year-old based on the *Exposure Factors Handbook* is 30 mg/day. The age ranges do not align between the 2 sources in this instance.

The Özkaynak et al. (2022) dust dose estimates for children above 1 year old are substantially lower than those in the *Exposure Factors Handbook* (U.S. EPA, 2017), while the estimates for children between 1 month and 1 year old are slightly higher. The authors of the Özkaynak et al. (2022) study offer some justification for the discrepancy by noting that the Handbook recommendations are a synthesis of several types of studies, including tracer studies that "[suffer] from various sources of uncertainty that could lead to considerable study-to-study variations." Biokinetic and activity pattern studies, such as Von Lindern et al. 2016 and Wilson et al. 2013 respectively, achieve results that are closer to the Özkaynak et al. (2022) results (see Figure 4, Özkaynak et al. (2022)).

5.2.2.4 Uncertainties in Interpretation of Monitored DEHP Dose Estimates

There are several potential challenges in interpreting available indoor dust monitoring data, including the following:

- Samples may have been collected at exposure times or for exposure durations not expected to be consistent with a presumed hazard based on a specified exposure time or duration.
- Samples may have been collected at a time or location when there were multiple sources of DEHP that included non-TSCA COUs.
- None of the identified monitoring data contained source apportionment information that could be used to determine the fraction of DEHP in dust samples that resulted from a particular TSCA or non-TSCA COU. Therefore, these monitoring data represent background concentrations of DEHP and are an estimate of aggregate exposure from all residential sources.
- Activity patterns may differ according to demographic categories (*e.g.*, stay at home/work from home individual vs. an office worker) that can affect exposures—especially to articles that continually emit a chemical of interest.
- Some indoor environments may have more ventilation than others, which may change across seasons.

5.3 Indoor Dust Modeling Weight of Scientific Evidence

See Section 5.1 for a detailed description of sources of uncertainties from CEM modeling and reconstruction of indoor dust scenarios from uncertainties to data variability.

6 CONCLUSION AND STEPS TOWARD RISK CHARACTERIZATION

Indoor Dust

For the indoor exposure assessment, EPA considered modeling and monitoring data. Monitoring data are expected to represent aggregate exposure to DEHP in dust resulting from all sources present in a home. Although it is not a good indicator of individual contributions of specific COUs, it provides a real-world indicator of total residential indoor dust exposure. For the modeling assessment of indoor dust exposures and estimation of the contribution to dust from individual COUs, EPA recreated plausible indoor environments using consumer products and articles commonly present in indoor spaces. Inhalation exposure from toys, flooring, furniture, wallpaper, and wire insulation include a consideration of dust collected on the surface of relatively large articles including flooring, furniture, and wallpaper in addition to smaller articles such as toys and wires that collect dust. Such exposures may lead to subsequent ingestion.

Although there are differences between modeled and monitoring, EPA determined that modeled and monitoring results were within an order of magnitude of each other. This observation further supports the approaches used in the modeling and monitoring indoor dust assessment. The monitoring estimates were used as a comparator to show that the modeled DEHP exposure estimates, aggregated across COUs per lifestage, were health-protective relative to residential monitored exposures (Table 4-4). Given the aggregate modeling estimates were greater than measurements from monitoring, EPA has supporting evidence that its conservative estimates of exposure from TSCA COUs may be health-protective.

This comparison was a key input to EPA's robust confidence in the overall health protectiveness of ther exposure assessment for ingestion of DEHP in indoor dust. The individual COU scenarios had a moderate to robust confidence in the exposure dose results and protectiveness of parameters used. Thus, the COU scenarios of the articles used in the indoor assessment were utilized in risk estimates calculations.

Consumer

All COU exposure dose results summarized in Section 3 have a moderate to robust confidence and therefore can be used for risk estimate calculations, and to determine risk to the various lifestages. The consumer assessment has low-, medium-, and high-exposure scenarios that represent use patterns of low-, medium-, and high-intensity uses. The high scenarios capture use patterns for high exposure potential from high frequency and duration use patterns, extensive mouthing behaviors, and conditions that promote greater migration of DEHP from products/articles to sweat and skin. Low- and medium-exposure scenarios represent less intensity in use patterns, mouthing behaviors, and conditions that promote DEHP migration to sweat and skin, capturing populations with different lifestyles.

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APPENDICES

Appendix A ACUTE, CHRONIC, AND INTERMEDIATE DOSE RATE EQUATIONS

The equations provided in this section were taken from the CEM user guide and associated appendices (accessed November 25, 2025).

A.1 Acute Dose Rate

Acute dose rate for inhalation of product used in an environment (CEM P_INH1 Model), such as indoor, outdoor, living room, garage, kitchen, bathroom, office, etc. was calculated as follows:

Equation_Apx A-1. Acute Dose Rate for Inhalation of Product Used in an Environment

$$ADR = \frac{C_{air} \times Inh \times FQ \times D_{ac} \times ED}{BW \times AT \times CF_1}$$

Where:

ADR	=	Acute dose rate (mg/kg-day)
C_{air}	=	Concentration of DEHP in air (mg/m^3)
Inh	=	Inhalation rate (m^3/h)
FQ	=	Frequency of product use (events/day)
D_{ac}	=	Duration of use (min/event), acute
ED	=	Exposure duration (days of product usage)
BW	=	Body weight (kg)
AT	=	Averaging time (days)
CF_1	=	Conversion factor (60 min/h)

For the ADR calculations, an averaging time of 1 day is used. The airborne concentration in the above equation is calculated using the high-end consumer product weight fraction, duration of use, and mass of product used. Therefore, in this case, the ADR represents the maximum time-integrated dose over a 24-hour period during the exposure event. CEM calculates ADRs for each possible 24-hour period over the 60-day modeling period (*i.e.,* averaging of hours 1–24, 2–25, etc.) and then reports the highest of these computed values as the ADR.

Acute dose rate for inhalation from article placed in environment (CEM A_INH1 Model) was calculated as follows, where the term environment refers to any indoor and outdoor location, such as garage, kitchen, bathroom, living room, car interior, daycare, school room, office, backyard (etc.):

Equation_Apx A-2. Acute Dose Rate for Inhalation from Article Placed in Environment

$$ADR_{Air} = \frac{C_{gas\_max} \times FracTime \times InhalAfter \times CF_1}{BW \times CF_2}$$

Equation_Apx A-3. Acute Dose Rate for Particle Inhalation from Article Placed in Environment

$$ADR_{Particulate} = \frac{DEHPRP_{air\_max} \times RP_{air\_avg} \times FracTime \times InhalAfter \times CF_1}{BW \times CF_2}$$

Equation_Apx A-4. Total Acute Dose Rate for Inhalation of Particulate and Air

$$ADR_{total} = ADR_{Air} + ADR_{Particulate}$$

Where:

ADR_{Air}	=	Acute dose rate, air (mg/kg-day)
$ADR_{Particulate}$	=	Acute dose rate, particulate (mg/kg-day)
ADR_{total}	=	Acute dose rate, total (mg/kg-day)
C_{gas_max}	=	Maximum gas-phase concentration (µg/m^3)
$DEHPRP_{air\_max}$	=	Maximum DEHP in respirable particle (RP) concentration, air (µg/mg)
RP_{air_max}	=	Maximum respirable particle concentration, air (mg/m^3)
$FracTime$	=	Fraction of time in environment (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 h/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1,000 µg/mg)

Acute dose rate for ingestion after inhalation (CEM A_ING1 Model) was calculated as follows:

Equation_Apx A-5. Acute Dose Rate from Ingestion After Inhalation

$$ADR_{IAI} = \frac{\left[\left(DCHPRP_{air\_max} \times RP_{air\_max} \times IF_{RP}\right) + \left(DCHPDust_{air\_max} \times Dust_{air\_max} \times IF_{Dust}\right) + \left(DCHPAbr_{air\_max} \times Abr_{air\_max} \times IF_{Abr}\right)\right] \times InhalAfter \times CF_1}{BW \times CF_2}$$

Where:

ADR_{IAI}	=	Acute dose rate from ingestion and inhalation (mg/kg-day)
$DEHPRP_{air\_max}$	=	Maximum DEHP in respirable particles (RP) concentration, air (µg/mg)
RP_{air_max}	=	Maximum RP concentration, air (mg/m^3)
IF_{TSP}	=	RP ingestion fraction (unitless)
$DEHPDust_{air\_max}$	=	Maximum DEHP in dust concentration, air (µg/mg)
$Dust_{air\_max}$	=	Maximum dust concentration, air (mg/m^3)
IF_{Dust}	=	Dust ingestion fraction (unitless)
$DEHPAbr_{air\_avg}$	=	Maximum DEHP in abraded particle concentration, air (µg/mg)
Abr_{air_avg}	=	Maximum abraded particle concentration, air (mg/m^3)
IF_{Abr}	=	Abraded particle ingestion fraction (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 hours/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1,000 mg/g)

Acute daily dose rate for ingestion of article mouthed (CEM A_ING2 Model) was calculated as follows:

Equation_Apx A-6. Acute Dose Rate for Ingestion of Article Mouthed

$$ADR = \frac{MR \times CA \times D_m \times ED_{ac} \times CF_1}{BW \times AT_{ac} \times CF_2}$$

Where:

ADR	=	Acute dose rate (mg/kg-day)
MR	=	Migration rate of chemical from article to saliva (mg/cm^2/h)
CA	=	Contact area of mouthing (cm^2)
D_m	=	Duration of mouthing (min/h)
ED_{ac}	=	Exposure duration, acute (days)
CF_1	=	Conversion factor (24 hours/day)
BW	=	Body weight (kg)
AT_{ac}	=	Averaging time, acute (days)
CF_2	=	Conversion factor (60 min/h)

See Section 2.2.3.1.9 for migration rate inputs and determination of these values.

Acute dose rate for incidental ingestion of dust (CEM A_ING3 model) was calculated as described below. Note that the article model named E6 in CEM calculates DEHP concentration in small particles, termed respirable particles (RP), and large particles, termed dust, which settle on the floor or surfaces. The model assumes the particles bound to DEHP are available via incidental dust ingestion assuming a daily dust ingestion rate and a fraction of the day that is spent in the zone with the DEHP-containing dust. The model uses a weighted dust concentration, shown Equation_Apx A-7.

Equation_Apx A-7. Acute Dust Concentration

$$Dust_{ac\_wgt} = \frac{\left(RP_{floor\_max} \times DEHPRP_{floor\_max}\right) + \left(Dust_{floor\_max} \times DEHPDust_{floor\_max}\right) + \left(AbArt_{floor\_max} \times DEHPAbArt_{floor\_max}\right)}{\left(TSP_{floor\_max} + Dust_{floor\_max} + AbArt_{floor\_max}\right)}$$

Where:

$Dust_{ac\_wgt}$	=	Acute weighted dust concentration (µg/mg)
RP_{floor_max}	=	Maximum RP mass, floor (mg)
$DEHPRP_{floor\_max}$	=	Maximum DEHP in RP concentration, floor (µg/mg)
$Dust_{floor\_max}$	=	Maximum dust mass, floor (mg)
$DEHPDust_{floor\_max}$	=	Maximum DEHP in dust concentration, floor (µg/mg)
$AbArt_{floor\_max}$	=	Maximum abraded particles mass, floor (mg)
$DEHPAbArt_{floor\_max}$	=	Maximum floor dust DEHP concentration (µg/mg)

Equation_Apx A-8. Acute Dose Rate for Incidental Ingestion of Dust

$$ADR = \frac{Dust_{ac\_wgt} \times FracTime \times DustIng}{BW \times CF}$$

Where:

ADR	=	Acute dose rate (mg/kg-day)
$Dust_{ac\_wgt}$	=	Acute weighted dust concentration (µg/mg)
$FracTime$	=	Fraction of time in environment (unitless)
$DustIng$	=	Dust ingestion rate (mg/day)
BW	=	Body weight (kg)
CF	=	Conversion factor (1,000 µg/mg)

The above equations assume DEHP can volatilize from the DEHP-containing article to the air and then partition to dust. Alternately, DEHP can partition directly from the article to dust in direct contact with the article. This is also estimated in A_ING3 Model assuming that the original DEHP concentration in

the article is known, and the density of the dust and dust-air and solid-air partitioning coefficients are either known or estimated as presented in E6. The model assumes partitioning behavior dominates or instantaneous equilibrium is achieved. This is presented as a worst-case or upper-bound scenario.

Equation_Apx A-9. Concentration of DEHP in Dust

$$C_d = \frac{C_{0\_art} \times K_{dust} \times CF}{K_{solid}}$$

Where:

C_d	=	Concentration of DEHP in dust (mg/mg)
C_{0_art}	=	Initial DEHP concentration in article (mg/cm^3)
K_{dust}	=	DEHP dust-air partition coefficient (m^3/mg)
CF	=	Conversion factor (10^6 cm^3/m^3)
K_{solid}	=	Solid air partition coefficient (unitless)

Once DEHP concentration in the dust is estimated the acute dose rate can be calculated. The calculation relies on the same upper-end dust concentration.

Equation_Apx A-10. Acute Dose Rate from Direct Transfer to Dust

$$ADR_{DTD} = \frac{C_d \times FracTime \times DustIng}{BW}$$

Where:

ADR_{DTD}	=	Acute dose rate from direct transfer to dust (mg/kg-day)
C_d	=	Concentration of DEHP in dust (mg/mg)
$FracTime$	=	Fraction of time in environment (unitless)
$DustIng$	=	Dust ingestion rate (mg/day)
BW	=	Body weight (kg)

Acute dose rate for ingestion of product swallowed (CEM P_ING1 Model) was calculated as follows:

Equation_Apx A-11. Acute Dose Rate for Ingestion of Product Swallowed by Mouthing

$$ADR = \frac{FQ_{ac} \times M \times WF \times F_{ing} \times CF_1 \times ED_{ac}}{BW \times AT_{ac}}$$

Where:

ADR	=	Acute dose rate (mg/kg-day)
FQ_{ac}	=	Frequency of use, acute (events/day)
M	=	Mass of product used (g)
WF	=	Weight fraction of chemical in product (unitless)
F_{ing}	=	Fraction of product ingested (unitless)
CF_1	=	Conversion factor (1,000 mg/g)
ED_{ac}	=	Exposure duration, acute (days)
AT_{ac}	=	Averaging time, acute (days)
BW	=	Body weight (kg)

The model assumes that the product is directly ingested as part of routine use and the mass is dependent on the weight fraction and use patterns associated with the product.

A.2 Non-Cancer Chronic Dose

Chronic average daily dose rate for inhalation of product used in an environment (CEM P_INH1 Model) was calculated as follows:

Equation_Apx A-12. Chronic Average Daily Dose Rate for Inhalation of Product Used in an Environment

$$CADD = \frac{C_{air} \times Inh \times FQ \times D_{cr} \times ED}{BW \times AT \times CF_1 \times CF_2}$$

Where:

$CADD$	=	Chronic average daily dose (mg/kg-day)
C_{air}	=	Concentration of chemical in air (mg/m^3)
Inh	=	Inhalation rate (m^3/h)
FQ	=	Frequency of use (events/year)
D_{cr}	=	Duration of use (min/event), chronic
ED	=	Exposure duration (years of product usage)
BW	=	Body weight (kg)
AT	=	Averaging time (years)
CF_1	=	Conversion factor (365 days/year)
CF_2	=	Conversion factor (60 min/h)

CEM uses two defaults inhalation rates which trace to the *Exposure Factors Handbook* (U.S. EPA, 2011c) (see Table_Apx A-1 notes)—one when the person is using the product and another after the use has ended. Table_Apx A-1 shows the inhalation rates by receptor age category for during and after product use.

Table_Apx A-1. Inhalation Rates Used in CEM Product Models

Age Group (years)	Inhalation Rate During Use (m^3/h) [a]	Inhalation Rate After Use (m^3/h) [b]
Adult (21+)	0.74	0.61
Youth (16–20)	0.72	0.68
Youth (11–15)	0.78	0.63
Child (6–10)	0.66	0.50
Small Child (3–5)	0.66	0.42
Infant (1–2)	0.72	0.35
Infant (<1)	0.46	0.23

[a] Table 6-2, light intensity values (U.S. EPA, 2011a)
[b] Table 6-1 (U.S. EPA, 2011a)

The inhalation dose is calculated iteratively at a 30-second interval during the first 24 hours and every hour after that for 60 days, taking into consideration the chemical emission rate over time, the volume of the house and each zone, the air exchange rate and interzonal airflow rate, and the exposed individual's locations and inhalation rates during and after product use.

Chronic average daily dose rate for inhalation from article placed in environment (CEM A_INH1 Model) was calculated as follows:

Equation_Apx A-13. Chronic Average Daily Dose Rate for Inhalation from Article Placed in Environment in Air

$$CADD_{Air} = \frac{C_{gas\_avg} \times FracTime \times InhalAfter \times CF_1}{BW \times CF_2}$$

Equation_Apx A-14. Chronic Average Daily Dose Rate for Inhalation from Article Placed in Environment in Particulate

$$CADD_{Particulate} = \frac{DEHPRP_{air\_avg} \times RP_{air\_avg} \times (1 - IF_{RP}) FracTime \times InhalAfter \times CF_1}{BW \times CF_2}$$

Equation_Apx A-15. Total Chronic Average Daily Dose Rate for Inhalation of Particulate and Air

$$CADD_{total} = CADD_{Air} + CADD_{Particulate}$$

Where:

$CADD_{Air}$	=	Chronic average daily dose, air (mg/kg-day)
$CADD_{Particulate}$	=	Chronic average daily dose, particulate (mg/kg-day)
$CADD_{total}$	=	Chronic average daily dose, total (mg/kg-day)
C_{gas_avg}	=	Average gas-phase concentration (µg/m^3)
$DEHPRP_{air\_avg}$	=	Average DEHP in respirable particles (RP) concentration, air (µg/mg)
RP_{air_avg}	=	Average RP concentration, air (mg/m^3)
IF_{RP}	=	RP ingestion fraction (unitless)
$FracTime$	=	Fraction of time in environment (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 hours/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1,000 µg/mg)

Chronic average daily dose rate for ingestion after inhalation (CEM A_ING1 Model) was calculated as described below. As noted previously, the CEM article model, E6, estimates DEHP concentrations in small and large airborne particles. Although these particles are expected to be inhaled, not all are able to penetrate the lungs and be trapped in the upper airway and subsequently swallowed. The model estimates the mass of DEHP bound to airborne small particles, RP, and large particles (*i.e.*, dust) that are inhaled and trapped in the upper airway. The fraction that is trapped in the airway is termed the ingestion fraction (IF). The mass trapped is assumed to be available for ingestion.

Equation_Apx A-16. Chronic Average Daily Dose Rate from Ingestion After Inhalation

$$CADD_{IAI} = \frac{\left[\left(DEHPRP_{air\_avg} \times RP_{air_{avg}} \times IF_{RP}\right) + \left(DEHPDust_{air\_avg} \times Dust_{air_{avg}} \times IF_{Dust}\right) + \left(DEHPAbr_{air\_avg} \times Abr_{air\_avg} \times IF_{Abr}\right)\right] \times InhalAfter \times CF_1}{BW \times CF_2}$$

Where:

$CADD_{IAI}$	=	Chronic average daily dose from ingestion after inhalation (mg/kg-day)
$DEHPRP_{air\_avg}$	=	Average DEHP in RP concentration, air (µg/mg)

RP_{air_avg}	=	Average RP concentration, air (mg/m^3)
IF_{RP}	=	RP ingestion fraction (unitless)
$DEHPDust_{air\_avg}$	=	Average DEHP dust concentration, air (µg/mg)
$Dust_{air\_avg}$	=	Average dust concentration, air (mg/m^3)
IF_{Dust}	=	Dust ingestion fraction (unitless)
$DEHPAbr_{air\_avg}$	=	Average DEHP in abraded particle concentration, air (µg/mg)
Abr_{air_avg}	=	Average abraded particle concentration, air (mg/m^3)
IF_{Abr}	=	Abraded particle ingestion fraction (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 hours/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1,000 mg/g)

Chronic average daily dose rate for ingestion of article mouthed (CEM A_ING2 Model) was calculated as described below. Note that the model assumes that a fraction of the chemical present in the article is ingested via object-to-mouth contact or mouthing where the chemical of interest migrates from the article to the saliva. See Section 2.2.3.1.9 for migration rate inputs and determination of these values.

Equation_Apx A-17. Chronic Average Daily Dose Rate for Ingestion of Article Mouthed

$$CADD = \frac{MR \times CA \times D_m \times ED_{cr} \times CF_1}{BW \times AT_{cr} \times CF_2}$$

Where:

$CADD$	=	Chronic average daily dose (mg/kg-day)
MR	=	Migration rate of chemical from article to saliva (mg/cm^2/h)
CA	=	Contact area of mouthing (cm^2)
D_m	=	Duration of mouthing (min/h)
ED_{cr}	=	Exposure duration, chronic (years)
CF_1	=	Conversion factor (24 hours/day)
AT_{cr}	=	Averaging time, chronic (years)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (60 min/h)

Chronic average daily rate for incidental ingestion of dust (CEM A_ING3 Model) was calculated as described below. Again, the article model in CEM E6 calculates DEHP concentration in small particles, termed RP, and large particles, termed dust, which settle on the floor or surfaces. The model assumes these particles, bound to DEHP, are available via incidental dust ingestion assuming a daily dust ingestion rate and a fraction of the day that is spent in the zone with the DEHP-containing dust. The model uses a weighted dust concentration, shown in the equation below.

Equation_Apx A-18. Chronic Dust Concentration

$$Dust_{cr\_wgt} = \frac{\left(RP_{floor\_avg} \times DEHPRP_{floor\_avg}\right) + \left(Dust_{floor\_avg} \times DEHPDust_{floor\_avg}\right) + \left(AbArt_{floor\_avg} \times DEHPAbArt_{floor\_avg}\right)}{\left(RP_{floor\_avg} + Dust_{floor\_avg} + AbArt_{floor\_avg}\right)}$$

Where:

$Dust_{cr\_wgt}$	=	Chronic weighted dust concentration (µg/mg)
RP_{floor_avg}	=	Average RP mass, floor (mg)
$DEHPRP_{floor\_avg}$	=	Average DEHP in RP concentration, floor (µg/mg)
$Dust_{floor\_avg}$	=	Average dust mass, floor (mg)
$DEHPDust_{floor\_avg}$	=	Average DEHP in dust concentration, floor (µg/mg)
$AbArt_{floor\_avg}$	=	Average abraded particles mass, floor (mg)
$DEHPAbArt_{floor\_avg}$	=	Average floor dust DEHP concentration (µg/mg)

Equation_Apx A-19. Chronic Average Daily Dose Rate for Incidental Ingestion of Dust

$$CADD = \frac{Dust_{cr\_wgt} \times FracTime \times DustIng}{BW \times CF}$$

Where:

$CADD$	=	Chronic average daily dose (mg/kg-day)
$Dust_{cr\_wgt}$	=	Chronic weighted dust concentration (µg/mg)
$FracTime$	=	Fraction of time in environment (unitless)
$DustIng$	=	Dust ingestion rate (mg/day)
BW	=	Body weight (kg)
CF	=	Conversion factor (1,000 µg/mg)

The above equations assume DEHP can volatilize from the DEHP-containing article to the air and then partition to dust. Alternately, DEHP can partition directly from the article to dust in direct contact with the article. This is also estimated in the A_ING3 Model assuming the original DEHP concentration in the article is known, and the density of the dust and dust-air and solid-air partitioning coefficients are either known or estimated as presented in the E6 CEM Model. That model assumes partitioning behavior dominates, or instantaneous equilibrium is achieved. This is presented as a worst-case or upper-bound scenario.

A.3 Intermediate Average Daily Dose

The intermediate doses were calculated from the average daily dose, ADD(µg/kg-day), CEM output for that product using the same inputs summarized in Table 2-9 for inhalation and Table 2-11 for dermal. EPA used professional judgment and product use descriptions to estimate events per day and per month for the calculation of the intermediate dose:

Equation_Apx A-20. Intermediate Average Daily Dose Equation

$$Intermediate\ Dose\ = \frac{ADD \times Event\ per\ Month}{Events\ per\ Day}$$

Where:

$Intermediate\ Dose$	=	Intermediate average daily dose, µg/kg-month
ADD	=	Average daily dose, µg/kg-day
$Event\ per\ Month$	=	Events per month, month^{-1}, see Table_Apx A-2
$Event\ per\ Day$	=	Events per day, day^{-1}, see Table_Apx A-2

Table_Apx A-2. Short-Term Event per Month and Day Inputs

Product	Events Per Day	Event Per Month
Flooring adhesives	1	2
Auto putties	1	2
Concrete sealant	1	2
Inductance loop sealant	1	2

A.4 Dermal Absorption Modeling

The equation used to estimate the dermal dose of DEHP associated with routine use of consumer liquid products and articles is as follows:

Equation_Apx A-21. Dermal Dose Per Exposure Event for Liquid and Solid Products

$$Dose\ per\ Event = Flux \times Duration\ of\ Use \times \frac{SA}{BW}$$

Where:

$Dose\ per\ Event$	=	Amount of chemical absorbed, mg/kg by body weight
$Flux$	=	Steady-state absorptive flux, mg/cm^2-hr
$Duration\ of\ use$	=	Extent of time specific product/article is in use (hours)
SA	=	Surface area of body parts in direct contact with product/article (cm^2)
BW	=	Body weight by lifestage (kg)

Acute dose rate for direct dermal contact with product or article was calculated as follows:

Equation_Apx A-22. Acute Dose Rate for Dermal

$$ADR_{Dermal} = Dose\ per\ Event \times Acute\ Frequency$$

Where:

ADR_{Dermal}	=	Acute dose rate for dermal contact, mg/kg-day by body weight
$Dose\ per\ Event$	=	Amount of chemical absorbed per use, mg/kg by body weight
$Acute\ Frequency$	=	Acute frequency of use, day^{-1}, see Table 2-11 for input parameters

Chronic average daily dose rate for direct dermal contact with product or article was calculated as follows:

Equation_Apx A-23. Chronic Average Daily Dose Rate for Dermal

$$CADD_{Dermal} = Dose\ per\ Event \times Chronic\ Frequency$$

Where:

$CADD_{Dermal}$	=	Chronic dermal rate for dermal contact, mg/kg-day by body weight
$Dose\ per\ Event$	=	Amount of chemical absorbed per use, mg/kg by body weight
$Chronic\ Frequency$	=	Chronic frequency of use, day^{-1}, see Table 2-11 for input parameters

Appendix B DERMAL SCREENING APPROACH DOSES AND MARGIN OF EXPOSURE FOR AIR BEDS REFINEMENT PROCESS

This appendix summarizes the screening and refined approach doses and margin of exposure (MOE) results for dermal exposures to air beds. Potential risk is first identified when comparing the risk estimates to a benchmark. The benchmark of 30 was estimated as described in *DEHP Non-cancer Human Health Hazard Technical Support Document* (U.S. EPA, 2025g). Potential risk was identified in the dermal exposure screening approach for some lifestages for air beds for high-intensity use scenario during direct dermal contact for all lifestages. The screening approach used a flux-limited approach that assumed an excess of DEHP in contact with the skin, which was independent of DEHP concentration in the article. EPA refined dermal exposure from air beds for all lifestages using an approach that considered DEHP concentration in the air bed and considers a barrier bedsheet (see Section 2.3.2 for refinement approach description). Table_Apx B-1 summarizes the screening approach doses and MOEs while highlighting those that pose potential risks. Table_Apx B-2 summarizes the refined approach doses and MOEs.

Table_Apx B-1. Screening Approach Air Beds Dermal Dose and Margin of Exposure Results

Exposure Level	Exposure Duration	Dose µg/kg bw day – By Individual Age Group							Margin of Exposure						
		Infants	Toddlers	Preschoolers	Middle Childhood	Young Teens	Teenagers	Adults	Infants	Toddlers	Preschoolers	Middle Childhood	Young Teens	Teenagers	Adults
High	Acute	175	155	140	116	96	88	84	6	7	8	9	11	12	13
Medium	Acute	31	13	11	8.1	6.3	5.7	6.0	35	82	100	140	180	190	180
Low	Acute	7.9	3.4	2.6	2.0	1.6	1.4	1.5	140	330	420	540	700	770	730
High	Chronic	17	15	14	11	9.5	8.7	8.3	64	72	80	96	120	130	130
Medium	Chronic	3.1	1.3	1.0	0.80	0.62	0.56	0.60	350	830	1,100	1,400	1,800	1,900	1,800
Low	Chronic	0.78	0.33	0.26	0.20	0.16	0.14	0.15	1,400	3,300	4,200	5,500	7,100	7,800	7,400

Inputs:
Duration of use for high-intensity use exposure level scenario: 857 minutes; medium, 480 minutes; and low, 120 minutes. The high-intensity exposure level represents sleep patterns that are more likely in infants, young teens, and teenagers. The medium-intensity use exposure level represents typical sleep patterns of adults and children. And the low-intensity exposure level represents shorter sleep patterns like napping.

Contact area for high-intensity use exposure level scenario, 50% of entire body surface area, and for both medium and low, 25% of face, hands, and arms. The high-intensity exposure level represents someone sleeping naked on the air bed. The medium- and low-intensity use exposure level selected surface contact area represents someone wearing clothing that covers most of their bodies, like long pants, short sleeves, and part of their faces are in direct contact with the air bed.

Table_Apx B-2. Refined Approach Air Beds Dermal Dose and Margin of Exposure Results

Exposure Level	Exposure Duration	Dose µg/kg bw day – By Individual Age Group							Margin of Exposure						
		Infants	Toddlers	Preschoolers	Middle Childhood	Young Teens	Teenagers	Adults	Infants	Toddlers	Preschoolers	Middle Childhood	Young Teens	Teenagers	Adults
High	Acute	60	53	48	40	33	30	29	18	21	23	28	33	36	38
Medium	Acute	3.9	1.7	1.3	1.0	0.79	0.72	0.76	280	650	840	1,100	1,400	1,500	1,500
Low	Acute	2.7E−04	1.1E−04	8.9E−05	6.8E−05	5.3E−05	4.8E−05	5.1E−05	4.1E06	9.7E06	1.2E07	1.6E07	2.1E07	2.3E07	2.1E07
High	Chronic	5.9	5.2	4.7	3.9	3.2	3.0	2.9	190	210	230	280	340	370	390
Medium	Chronic	0.39	0.17	0.13	1.0E−01	7.8E−02	7.1E−02	7.5E−02	2.8E03	6.6E03	8.5E03	1.1E04	1.4E04	1.6E04	1.5E04
Low	Chronic	2.6E−05	1.1E−05	8.8E−06	6.8E−06	5.2E−06	4.8E−06	5.1E−06	4.2E07	9.8E07	1.3E08	1.6E08	2.1E08	2.3E08	2.2E08

Inputs:
Duration of use for high-intensity use exposure level scenario, 857 minutes; medium, 480 minutes; and low, 120 minutes. The high-intensity exposure level represents sleep patterns that are more likely in infants, young teens, and teenagers. The medium intensity use exposure level represents typical sleep patterns of adults and children. And the low-intensity exposure level represents shorter sleep patterns like napping.

Contact area for high-intensity use exposure level scenario, 50% of entire body surface area, and for both medium and low, 25% of face, hands, and arms. The high-intensity exposure level represents someone sleeping naked on the air bed covered with a bedsheet. The medium- and low-intensity use exposure level selected surface contact area represents someone wearing clothing that covers most of their bodies, like long pants, short sleeves, and part of their faces are in direct contact with the air bed covered with a bedsheet.