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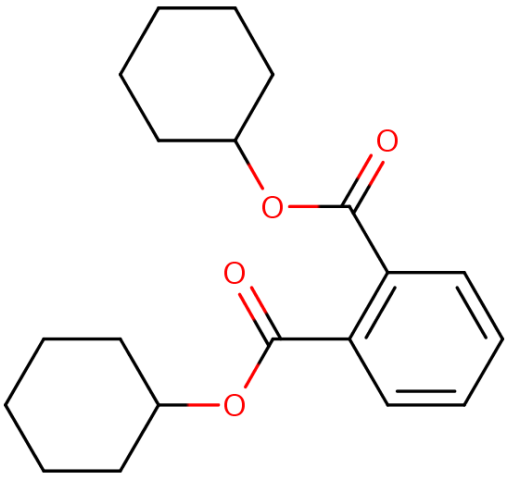
Draft Consumer and Indoor Dust Exposure Assessment for Dicyclohexyl Phthalate (DCHP)

Technical Support Document for the Draft Risk Evaluation

CASRN 84-61-7



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ABBREVIATIONS AND ACRONYMS

ACC	American Chemical Council
ADR	Average (or acute) dose rate
CADD	Chronic Average Daily Dose
CASRN	Chemical Abstracts Service Registry Number
CDC	Center for Disease Control and Prevention
CDR	Chemical Data Reporting
CEM	Consumer Exposure Model
CPSC	Consumer Product Safety Commission
CPSIA	Consumer Product Safety Improvement Act
COU	Condition of use
DBP	Dibutyl phthalate
DCHP	Dicyclohexyl phthalate
DIY	Do-it-yourself
FDA	Food and Drug Administration
HPCDS	High Priority Chemicals Data System
MCCEM	Multi-Chamber Concentration and Exposure Model
NHANES	National Health and Nutrition Examination Survey
OPPT	Office of Pollution Prevention and Toxics
POD	Point of departure
PVAc	Polyvinyl acetate
PVC	Polyvinyl chloride
SDS	Safety data sheet
SVOC	Semi volatile organic compound
TSCA	Toxic Substances Control Act

SUMMARY

This technical document is in support of the Toxic Substances Control Act (TSCA) *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). It provides detailed descriptions of DCHP consumer and indoor exposure assessment. DCHP is a white, crystalline solid with a mild aromatic odor used as a plasticizer in the production of plastics, adhesives, rubber, and resins; see *Draft Physical Chemistry and Fate and Transport Assessment for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024e). DCHP, either alone or in combination with other phthalates, is also commonly used in the production of plastics and other polymers, in sealants and adhesives for paper food packaging, and as a preservation agent in peroxides.

This draft assessment considers human exposure to DCHP in consumer products resulting from TSCA conditions of use (COUs). The major routes of exposure considered were ingestion via mouthing, ingestion of suspended dust, ingestion of settled dust, inhalation, and dermal exposure. For inhalation and ingestion exposures, EPA used the Consumer Exposure Model (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 *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) outside of CEM because the exposure duration for intermediate scenarios is outside the 60-day modeling period CEM uses. Acute exposures are for an exposure duration of 1 day, chronic exposures are for an exposure duration of 1 year, and intermediate are for an exposure duration of 30 days. Confidence in the CEM inhalation and ingestion modeling estimates were robust or moderate depending on product or article scenario. For each scenario, high, medium, and low 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. Dermal exposures for both liquid products and solid articles were calculated in a spreadsheet outside of CEM; see *Draft Consumer Exposure Analysis for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024b). CEM dermal modeling uses a dermal model approach that assumes infinite DCHP 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 depending on uncertainties associated with input parameters.

The highest DCHP exposure estimated for all scenarios was for ingestion via mouthing of indoor dust collected on children's toys for infants, toddlers, and preschoolers (up to 5 years old). Because mouthing tendencies decrease or cease entirely for children 6 to 10 years old, exposure from mouthing is expected to be larger for infants to 5-year-old children. Because products/articles that do not have a mouthing estimate are not expected to have direct mouthing exposures, the ingestion exposure estimates fall below all other exposure routes. Dermal exposures were overall highest followed by inhalation and ingestion across scenarios, COUs, and lifestages. The range of inhalation and ingestion doses for each scenario and lifestage covered several orders of magnitude due to (1) the wide range of DCHP content (weight fractions) for adhesives; (2) wide range of article exposure durations; and (3) various surface area options for similar articles for the low, medium, and high scenario for children's toys. The dermal dose range was smaller for all scenarios driven mainly by exposure durations and frequencies.

1 INTRODUCTION

DCHP is assigned one CASRN, 84-61-7 under various names: 1,2-benzenedicarboxylic acid, dicyclohexyl ester; phthalic acid, dicyclohexyl ester; and diclohexyl 1,2-benzenedicarboxylate. DCHP is a granular solid primarily used as a plasticizer in polyvinyl chloride (PVC) in consumer, commercial, and industrial applications—although it is also used in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as for other applications.

The consumer and indoor dust exposure assessment requires the identification of products and articles within each TSC condition of use (COU). These included PVC used in solid articles such as electronics containing dye adhesives, foil lacquers, paperboard, and cellophane for packaging, polyvinyl alcohol (PVA), hardener catalysts for concrete and masonry; liquid products including adhesives, sealants, and automotive and construction adhesives. EPA further assembled reasonably available 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 additional COUs for inclusion in the draft risk evaluation (see Table 1-1 for consumer-specific COUs). Consumer products and articles were identified and matched to COUs. Weight fractions of DCHP in specific items were then gathered from a variety of sources, such as safety data sheets (SDSs), databases, and literature reviewed publications. These data were used in this assessment in a screening approach as described in Section 2.1. Although children's toys were not identified as a COU of DCHP, EPA considered data identified in the High Priority Chemicals Data System (HPCDS) (WSDE, 2020) database. The Agency used the identified data to develop children's toys exposure scenarios. This document provides a summary of the exposure doses calculated.

The migration of DCHP 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 DCHP has not been well characterized. The identified uses can result in exposures to consumers and bystanders (non-product users that are incidentally exposed to the product). For all the DCHP 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 DCHP across COUs and various age groups.

Because PVC and plastic products are ubiquitous in modern indoor environments, and since DCHP is not chemically bound to many consumer products and articles in which it is incorporated, it can leach, migrate, or evaporate (to a lesser extent based on physical and chemical properties) 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 as they crawl on the ground and pull-up on ledges, which increases hand-to-dust contact. Children in this age group also frequently place their hands and objects in their mouths. Therefore, estimated exposures were assessed and compared for children below and above 2 years old.

225 **Table 1-1. Consumer Conditions of Use Table**

Life Cycle Stage[a]	Category[b]	Subcategory of Use[c,e]	References
Consumer Uses	Adhesives and sealants	Adhesives and sealants	(DeWALT, 2024; Lord Corporation, 2024; Midwest Technology Products, 2024; MKT, 2024; Permatex, 2024, 2021; DeWALT, 2020; MKT, 2018; LORD Corporation, 2017)
	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	(U.S. EPA, 2020a; AIA, 2019; MEMA, 2019; U.S. EPA, 2019a)
	Other	Other consumer articles that contain dicyclohexyl phthalate from: inks, toner, and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper products, textiles, products using cellulose film, etc.)	(HYDRO-GARD, 2024; Hallstar, 2022; LANXESS, 2021; U.S. EPA, 2020b; Earthjustice, 2019; MEMA, 2019; U.S. EPA, 2019b; Gans Ink and Supply, 2018; HYDRO-GARD, 2017a, b; CPSC, 2015)
Disposal	Disposal	Disposal	

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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 judgement.
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 and articles containing DCHP were matched with TSCA COUs appropriate for the anticipated use of the item. Table 2-1 summarizes the consumer exposure scenarios by COU for each product example(s), the relevant exposure routes, an indication of scenarios also used in the indoor dust assessment, and whether the analysis was done qualitatively or quantitatively. The indoor dust assessment uses consumer product information for selected articles with the goal of recreating the indoor environment. The consumer articles included in the indoor dust assessment were selected for their potential to have large surface area for dust collection.

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. A qualitative analysis was conducted when data were not available for modeling. The qualitative analysis allowed for a discussion of exposure potential based on physical and chemical properties, or available monitoring data should monitoring data be available, even in the absence of quantitative modeling estimates. 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 CEM Version 3.2 (U.S. EPA, 2023). Dermal exposure to DCHP-containing consumer products was estimated using a computational framework implemented within a spreadsheet. Refer to Dermal Modeling Approach in Section 2.3 for a detailed description of dermal approaches, rationale for analyses conducted outside CEM, and consumer specific dermal parameters and assumptions for exposure estimates. For each exposure route, EPA used the 10th percentile, average, and 95th percentile value of an input parameter (*e.g.*, weight fraction, surface area, etc.) to characterize low, medium, and high exposure, where possible and according to condition of use. If only a range was reported, EPA used the minimum and maximum of the range as the low and high values, with the average of the minimum and maximum used for the medium scenario. See Section 2.1 for details about the identified weight fraction data and statistics used in the low, medium, and high exposure scenarios. All CEM and dermal spreadsheet calculations' inputs, sources of information, assumptions, and exposure scenario descriptions are available in the *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2024b).

Based on reasonably available information from the systematic review on consumer conditions of use and indoor dust studies, inhalation of DCHP is possible through DCHP emitted from products and articles and DCHP sorbed to indoor dust and particulate matter. A detailed discussion of indoor dust references, sources, and concentrations is available in Sections 4. Due to DCHP's low volatility,

negligible or very small gas-phase inhalation exposures are expected. However, DCHP's physical and chemical properties, such as low vapor pressure, low solubility, and high 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 4.1 reports concentrations of DCHP in settled dust from indoor environments. Due to the presence of DCHP in indoor dust, inhalation and ingestion of suspended dust as well as ingestion of settled dust are both considered as exposure routes in this consumer assessment.

Oral exposure to DCHP 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 DCHP, oral and dermal exposures to consumers were assessed.

Qualitative analysis describing low exposure potential were discussed in Section 2.1, mainly based on physical and chemical properties or product and article use descriptions. For example, given the low volatility of DCHP, emissions to air from solid articles are expected to be relatively low. As such, articles with a small surface area (< ~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 this assumption, a CEM test run for a generic 1 m^2 item with 30 percent DINP content by weight was carried out. 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 negligeable as compared to potential exposure by dermal and mouthing routes, which were assessed as appropriate, see *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). Similarly, solid articles not expected to be mouthed (*e.g.*, building materials, outdoor furniture, etc.) were not assessed for mouthing exposure. Furthermore, as DCHP is a low volatility solid that is used primarily as a plasticizer in manufacturing, potential take-home exposures are likely too small in comparison to the scenarios considered in this assessment, hence take-home exposures were not further explored.

EPA assessed acute, chronic, and intermediate exposures to DCHP from consumer COUs. For the acute dose rate calculations, an averaging time of one day is used to represent the maximum time-integrated dose over a 24-hour period in which the exposure event occurs. The chronic dose rate is calculated iteratively at a 30-second interval during the first 24 hours and every hour after that for 60 days, and averaged over one year. Professional judgment and product use descriptions were used to estimate number of events per day and per month for each product, for use in the calculation of the intermediate dose. Whenever professional judgment was used, EPA provided a rationale and description of selected parameters.

2.1 Products and Articles with DCHP 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, which are present within indoor environments for the duration of their useful life, which may be several years. The preferred data sources for DCHP content in U.S. consumer goods were safety data sheets (SDS) for specific products or articles with reported DCHP content, peer review literature providing measurements of DCHP in consumer goods purchased in the U.S., and government reports originating in the U.S. with manufacturer reported concentrations. In instances where these data from preferred sources were not available, DCHP content in specific products and articles provided in non-U.S. sources and the EPA Chemical Data Reporting (CDR) rule were reviewed. Manufacturing practices and regulations for

DCHP in consumer goods are comparable between high income countries and the U.S., so it is reasonable to assume that similarly formulated products may be available across these regions. When no data could be found for a specific type of product or article identified as likely to contain DCHP, weight fractions from similar products for general classes of items were used (*e.g.*, non-specific adhesives, furniture, or textiles). DCHP weight fractions reported in the CDR database were used only when no other data could be found for a reported product category. 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 is added to other components during the manufacturing process of the finished good. There are considerable uncertainties in weight fraction when using CDR data. The concentration value reported in CDR may be regarded as an upper boundary for the DCHP content in finished consumer goods.

EPA further evaluated the products and articles identified to ensure that data was representative of items which may expose U.S. consumers to DCHP. 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 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.

In addition to DCHP 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 provides a summary of specific products and articles with DCHP content identified for each item, and Table 2-1 provides a summary of TSCA COUs determined for each item and exposure pathways modeled.

2.1.1 Solid Articles

DCHP has been described to be used in a variety of solid articles. However, weight fraction data for solid articles containing DCHP and currently sold in the U.S. were limited. Consumer product data were obtained from SDSs and the High Priority Chemicals Data System (HPCDS) (WSDE, 2020), a database compiling manufacturer reporting requirements per Washington and Oregon safe children's product regulations. The DCHP weight fraction data used in this assessment from the HPCDS database corresponds to the 2017 to 2024 reporting period. Concentration ranges (*e.g.*, 100–500 ppm) based on test results or manufacturer knowledge are provided. Additionally, specific products or articles are not identified; only generic categories (*e.g.*, toys/games) are provided.

Given the high molecular weight (330.43 g/mol) and low vapor pressure (8.69×10^{-7} mmHg) of DCHP, 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, see articles with potential for semi-routine dermal exposure. For solid articles where only mouthing and/or dermal contact were assessed, DCHP content is provided for context and was not used directly in exposure calculations for these routes (see Section 2.3 for details). For articles assessed for mouthing and/or dermal contact the weight fraction data is used to confirm the presence of DCHP in the article but these data are not used in the dermal and mouthing modeling, see Sections 2.2.3.1 (mouthing) and 2.3 (dermal). Furthermore, dermal, and mouthing exposures assessments include high, medium, and low intensity use scenarios for each article using a range of modeling input parameters described in the corresponding sections, such as dermal absorption related parameters and chemical migration rates (mouthing).

Children's Toys

Although children's toys were not identified as a COU of DCHP, EPA considered data identified in the High Priority Chemicals Data System (HPCDS) (WSDE, 2020) database. The Agency used the identified data to develop children's toys exposure scenarios. This document provides a summary of the exposure doses calculated. Children's toys were assessed for DCHP exposure by the inhalation, dust ingestion, dermal, and mouthing routes of exposure. Under the Consumer Product Safety Improvement Act (CPSIA) final rule that went into effect on April 25, 2018, Congress permanently prohibited the sale of children's toys or childcare articles containing concentrations of more than 0.1 percent DCHP. While it is possible that some individuals may have children's toys in the home that were produced before the regulation was enacted and/or toys may be sold with non-compliant DCHP content, such scenarios were not modeled because relevant data were unavailable. The HPCDS database contained data for DCHP measurements in 20 toy/game items. While there is some uncertainty about the materials these items are manufactured from, based on the limited descriptions in the database, EPA determined that these items are likely composed primarily of plastic and rubber components. DCHP content was reported to be less than 100 ppm (<0.01%) in all toy items. (WSDE, 2020). As such, all scenarios for children's toys were modeled with a weight fraction of 0.0001 w/w (weight per weight).

Electronics containing Dye Adhesive

DCHP was identified at 0.1 to 1 percent in dye attach adhesive used in wirebond packaging for semiconductor devices or in automotive cameras (Henkel Corporation, 2019). As the adhesive is used in small quantities and contained within the electronic articles, no exposures are expected during potential use of these items.

Other articles with potential for semi-routine dermal exposure

In the 2020 CDR database, a manufacturer reported that DCHP or a DCHP containing additive was produced for use in small rubber or plastic items with routine contact. Specific items manufactured and weight fraction of DCHP in finished goods were not reported. To determine the kinds of articles which might contain DCHP, U.S. plasticizer manufacturer websites were surveyed for descriptions of use. Only one manufacturer could be identified which clearly markets a plasticizer containing DCHP at present (Parchem, 2024). Potential uses for the DCHP containing plasticizer listed on the product page include heat-seal applications, food wrappers, labels, and packaging adhesives; pharmaceutical labels; foil lacquers; cellophane lacquers; nitrocellulose; ethylcellulose; chlorinated rubber; PVAc; PVC; and printing inks. Consumers may come into contact with materials containing DCHP through handling various packaging, labels, and films. For example, films may be used as wrapping for gift baskets, florist supplies, and product windows on boxes. As films are typically used in smaller items, the primary exposure route is through dermal contact when handling the packaged goods. Although DCHP content was not reported or measured in specific products, this scenario was included for dermal exposure calculations, which does not use weight fractions. Dermal contact events are likely short and/or infrequent, but an individual could have appreciable daily contact with multiple items. The items are not expected to be mouthed and the likelihood of inhalation exposure is minimal due to their small surface area and limited time spent in an indoor environment before disposal. Some of the listed uses, such as food packaging materials, may not be chemical substances under TSCA. However, information gathered from these uses was used as a proxy for packaging, wrappers, and labels related to COUs in this evaluation.

Outdoor Coated Surfaces/Seating

DCHP content was identified in two hardener catalysts which are used with their associated

waterproofing coating resin products in applications such as concrete, masonry, plaza decks, roof decks, balconies, terraces, and stadium seating. The reported DCHP content in the two products was 50 percent (CETCO, 2018) and 40 to 55 percent (Hydro-Gard LLC, 2017). However, both products are added to resin in small quantities, resulting in significantly lower weight fractions on the finished surface. Based on technical documentation provided by manufacturers, the weight fraction of DCHP in applied surface coatings is expected to be between 0.001 to 0.024 w/w, depending upon the resin used and mixing ratios selected. Dermal exposures were modeled for a scenario where consumers sit on coated surfaces (*e.g.*, on seats at a sporting event or directly on a terrace). Based on DCHP's waterproofing and weather resistant properties and the examples being mainly outdoors EPA anticipated use is outdoors only and air exchange rates are large, thus inhalation exposure is expected to be negligible.

2.1.2 Liquid and Paste Products

Liquid and paste products with DCHP content were identified by manufacturer SDS. Products with similar DCHP content and expected use patterns were grouped together for modeling as described below. Note that for liquid and paste products where only dermal exposure was assessed, DCHP content is provided here for context and not used directly in exposure calculations for these routes (see Sections 2.2.3 and 2.3 for details).

Adhesives and Sealants for Small Repairs

Two adhesive products were identified with DCHP content. The first product is a multi-purpose household glue for small repairs, with DCHP content of 1 to 5 percent (ITW Permatex, 2018). The second product is an adhesive activator used in small repairs, with DCHP content ranging from 10 to 20 percent (WEICON GmbH & Co. KG, 2018). Both products are used in small amounts and have very short working times (<5 min), which limits the potential for inhalation exposure. However, if dermal exposure occurs during use it is possible that the product may not be washed off immediately, potentially resulting in significant exposure. As such, both products were modeled for dermal exposure only.

Automotive or Construction Adhesives

Two bonding adhesives for vehicle maintenance/repair or construction applications were identified. The reported DCHP contents were 1 to 5 percent (LORD Corporation, 2017) and 3 to 5 percent (Ford Motor Company, 2015). The identified products may be used for large repairs to vehicle bodies and were therefore assessed for both inhalation and dermal exposure. DCHP weight fractions used in low, medium, and high exposure scenarios were 0.01, 0.035, and 0.05 w/w.

Table 2-1 provides a summary of TSCA COUs determined for each item and exposure pathways modeled.

454 **Table 2-1. Summary of Consumer COUs, Exposure Scenarios, and Exposure Routes**

Consumer Condition of Use Category	Consumer Condition of Use Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes					
				Suspended Dust and Vapor Inhalation	Dermal	Ingestion			Qualitative / Quantitative [d]
						Suspended Dust	Settled Dust	Mouthing	
Adhesives and sealants	Adhesives and sealants	Auto or construction bonding adhesive	Use of product in DIY [a] large-scale home repair activities. Direct contact during use; inhalation of emissions during use.	✓	✓	✗	✗	✗	Quantitative
Adhesives and sealants	Adhesives and sealants	Adhesives for small repairs	Use of product in DIY [a] small-scale home repair activities. Direct contact during use.	✗	✓	✗	✗	✗	Quantitative
Plasticizer in other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Plasticizer in other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Small articles with the potential for semi-routine contact: labels, nitrocellulose; ethylcellulose; chlorinated rubber; PVAc; PVC	Direct contact during use	✗ [b]	✓	✗	✗	✗	Quantitative
Not identified as a COU of DCHP [e]	Not identified as a COU of DCHP [e]	Children's toys	Collection of toys. Direct contact during use; inhalation of emissions / ingestion of airborne particulate; ingestion by mouthing.	✓	✓	✓	✓	✓	Quantitative
Other	Other consumer articles that contain dicyclohexyl phthalate from: inks, toner and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper	Outdoor coated surfaces/seating	Direct contact during use	✗ [c]	✓	✗	✗	✗	Quantitative

Consumer Condition of Use Category	Consumer Condition of Use Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes					
				Suspended Dust and Vapor Inhalation	Dermal	Ingestion			Qualitative / Quantitative [d]
						Suspended Dust	Settled Dust	Mouthing	
	products, textiles, products using cellulose film, etc.)								
Other	Other consumer articles that contain dicyclohexyl phthalate from: inks, toner and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper products, textiles, products using cellulose film, etc.)	Small articles with the potential for semi-routine contact: labels, and packaging adhesives, foil and cellophane lacquers, and printing inks	Direct contact during use	✗ [b]	✓	✗	✗	✗	Quantitative
Other	Other consumer articles that contain dicyclohexyl phthalate from: inks, toner and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper products, textiles, products using cellulose film, etc.)	Electronics containing dye adhesive	No exposures expected	✗	✗	✗	✗	✗	Qualitative
Disposal	Disposal	Down the drain products and articles	Down the drain and releases to environmental media	✗	✗	✗	✗	✗	Qualitative
Disposal	Disposal	Residential end-of-life disposal, product demolition for disposal	Product and article end-of-life disposal and product demolition for	✗	✗	✗	✗	✗	Qualitative

Consumer Condition of Use Category	Consumer Condition of Use Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes					
				Suspended Dust and Vapor Inhalation	Dermal	Ingestion			Qualitative / Quantitative [d]
						Suspended Dust	Settled Dust	Mouthing	
			disposal						

DIY [a] – Do-it-Yourself

✓ Scenario is considered either qualitatively or quantitatively in this assessment.

✘ Scenario was deemed unlikely based on low volatility and small surface area, likely negligible gas and particle phase concentration for inhalation, low possibility of mouthing based on product use patterns and targeted population age groups, and/or low possibility of dust on surface due to barriers or low surface area for dust ingestion.

✘ [b] Scenario was deemed unlikely based on low volatility and small surface area and likely negligible gas and suspended particle phase concentration.

✘ [c] Outdoor use with significantly higher ventilation minimizes inhalation.

[d] Quantitative applies to green check marks and qualitative applies to red "x" marks for the routes that were deemed unlikely (Sections 2.1.1 and 2.1.2 or assessed qualitatively using physical and chemical properties (Disposal).

[e] Although children's toys were not identified as a COU of DCHP, EPA considered data identified in the High Priority Chemicals Data System (HPCDS) (WSDE, 2020) database and used it to provide an exposure assessment.

Qualitative Assessments

EPA performed qualitative assessments of the COU summarized in Table 2-2. A qualitative discussion using physical and chemical properties and monitoring data for environmental media was performed to support conclusions about down-the-drain and disposal practices and releases to the environment.

Table 2-2. 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	No quantitative assessment done due to limited information on source attribution of the consumer COUs in drain water or wastewater.
Disposal	Disposal	Residential end-of-life disposal, product demolition for disposal	No quantitative assessment done due to limited information on source attribution of the consumer COUs in landfills.
Other	Other consumer articles that contain dicyclohexyl phthalate from: inks, toner and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper products, textiles, products using cellulose film, etc.)	Electronics containing dye adhesive	No exposures are expected during potential use of these items because the adhesive is used in small quantities and contained within the electronic articles.

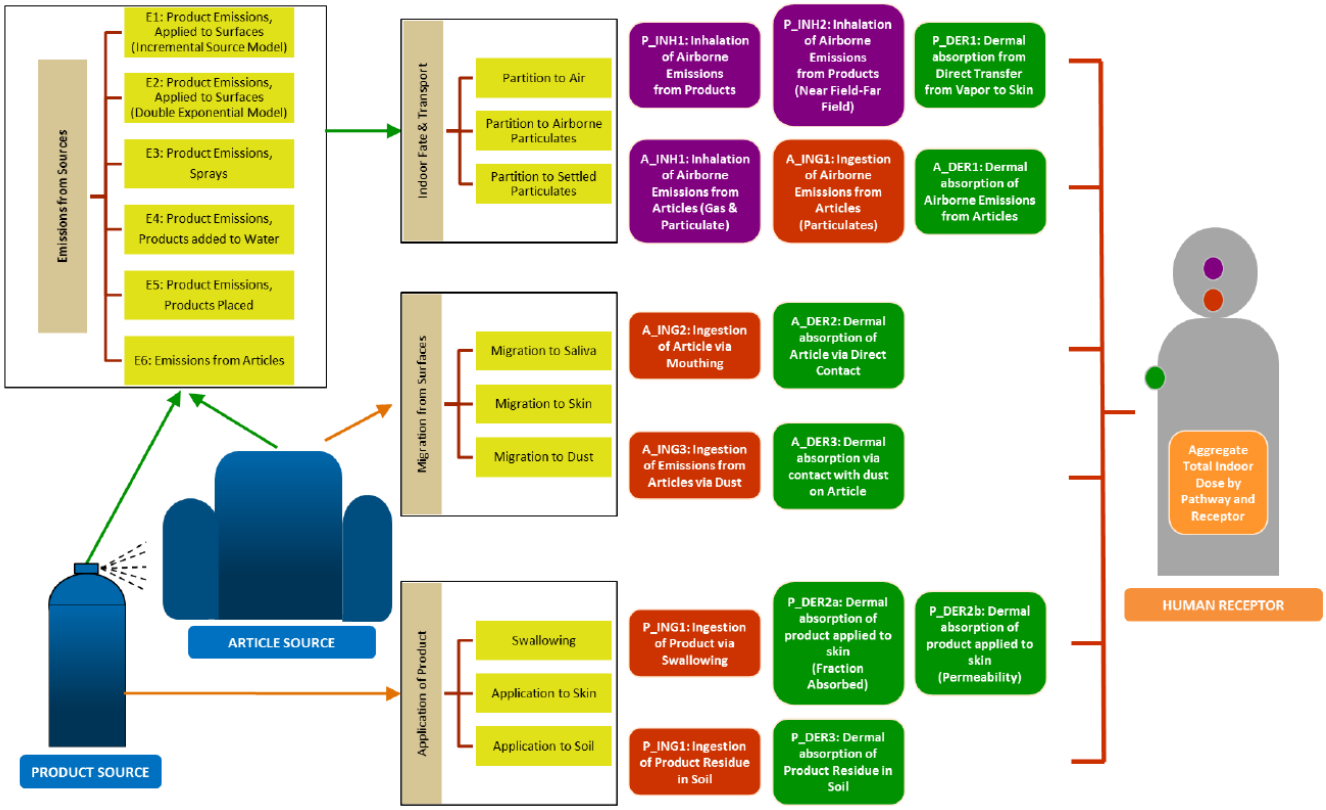
Environmental releases may occur from consumer products and articles containing DCHP via the end-of-life disposal and demolition of consumer products and articles in the built environment or landfills, as well as from the associated down-the-drain release of DCHP. It is difficult for EPA to quantify these end-of-life and down-the-drain exposures due to limited information on source attribution of the consumer COUs. In previous assessments, EPA has considered down-the-drain analysis for consumer products scenarios where there is reasonably foreseen exposure scenarios where it can be assumed the consumer products (*e.g.*, sealants) may be discarded directly down-the-drain. For example, adhesives and sealants can be disposed down-the-drain when users wash their hands, brushes, sponges, and other product applying tools. Although EPA acknowledges that there may be DCHP releases to the environment via the cleaning and disposal of adhesives and sealants, the Agency did not quantitatively assess these scenarios due to limited information, monitoring data, or modeling tools. In addition, DCHP- containing products can be disposed and taken to landfills when users no longer have use for them or the products have reached the product shelf life. All other solid products and articles in Table 2-1 can be disposed in landfills, or other waste handling locations that properly manage the disposal of products like adhesives and sealants and other solid articles. DCHP is expected to be persistent as it leaches from consumer products disposed of in landfills. Due to slight water solubility, DCHP is likely to be present in landfill leachate up to its aqueous limit of solubility (1.48 mg/L). However, due to its affinity for organic carbon, DCHP is expected to be immobile in groundwater. And even in cases where landfill leachate containing DCHP were to migrate to groundwater, DCHP would likely partition from groundwater to organic carbon present in the subsurface (U.S. EPA, 2024d).

2.2 Inhalation and Ingestion Modeling Approach

The CEM Version 3.2 (U.S. EPA, 2023) was selected for the consumer exposure modeling as the most appropriate model based on the type of input data available for DCHP-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 DCHP, such as weight fractions, product density, room of use, frequency, and duration of use, see Section 2.2.3 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 DCHP).

CEM has capabilities to model exposure to DCHP 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 be several years. Figure 2-1 displays the embedded models within CEM 3.2.



The green squares in the figure refer to dermal exposures, red squares refer to ingestion exposures, and purple squares refer to inhalation exposures within CEM.

Figure 2-1. Consumer Pathways and Routes Evaluated in this Assessment

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 SVOCs. There are six emission calculation profiles within CEM (E1 to 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 https://www.epa.gov/tsca-screening-tools.

CEM 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 perform 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, and 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 Center 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) → Adult
- Youth 2 (16–20 years) → Teenager and young adult
- Youth 1 (11–15 years) → Young teen
- Child 2 (6–10 years) → Middle childhood
- Child 1 (3–5 years) → Preschooler
- Infant 2 (1–2 years) → Toddler
- Infant 1 (<1 year) → Infant

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, and the air flows between the two zones. Following product use, the user and bystander may follow one of three pre-defined 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 the majority of the day (20 hours).

CEM default air exchange rates for the building are from the *Exposure Factors 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 2.2.3 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/hour. Bedrooms, bathrooms, laundry rooms, and utility rooms are considered less open, and an interzonal ventilation rate of 107 m^3/hour 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 $1x10^{-30}$ 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 like suspended and settled particulate, are subject to cleaning and ventilation losses. Abraded particles, both in the suspended and settled phases, are not assumed to be in equilibrium with the air phase. Hence, 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 DCHP 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 DCHP has partitioned, as well as 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 1-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 DCHP consisted of both products and articles. The embedded models within CEM 3.2 that were used for DCHP are listed in Table 2-3 below. As dermal exposure was modeled separately, only inhalation and ingestion routes were evaluated in CEM.

Table 2-3. CEM 3.2 Model Codes and Descriptions

Model Code	Description
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_ING1	Ingestion of Product Swallowed
P_INH2	Inhalation of Product Used in an Environment

Table 2-4 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 mapped to multiple scenarios, and in other cases one scenario mapped to multiple COUs. Table 2-4 provides data on emissions model and exposure pathways modeled for each exposure scenario. Emissions models were selected based upon physical and chemical properties of the product or article 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 would mouth flooring or wallpaper, hence 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 DCHP sorbed to dust/PM and were therefore not modeled for these routes (A_ING1, A_ING3). For products and articles assessed for dermal exposure only (concrete sealants on outdoor seating surfaces, small articles with semi-routine contact, and adhesives for small repairs), modeling was performed outside of CEM as described in Section 2.3; these items are therefore not included in Table 2-4.

Table 2-4. 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	Exposure Route	Exposure Pathway Model and CEM Saved Analysis
Adhesives and sealants Adhesives and sealants	Automotive Adhesives	E1	Inhalation	Glue and adhesives (small scale); P_INH2 (Near-field/Far-field)
Not identified as a COU of DCHP	Children's Toys	E6	Inhalation, ingestion of suspended and settled dust, and mouthing	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys); A_INH1, A_ING1, A_ING2, A_ING3

In total, the specific products representing three COUs categories and three subcategories for DCHP were mapped to five 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 DCHP in air and dust result in increased exposure. This may occur due to article specific characteristics that allow for higher emissions of DCHP to air, and/or environment specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control DCHP emission rates from articles in CEM 3.2 models are weight fraction of DCHP 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 results in increased emissions and greater exposure to DCHP. 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 2-5. Note that articles not modeled for inhalation exposure are not included in the table.

Weight fractions of DCHP were calculated for children's toys as outlined in Section 2.1.1. Material density was assumed to be a standard value for PVC of 1.4 g/cm^3. Article surface layer thickness was 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.

Due to the high variability and uncertainty of article surface areas, high, medium, and low values were estimated with the goal of capturing a reasonable range of values for this parameter. Children's toys generally have a small surface area for an individual item, but consumers may have many of the same type of toy in a home. As such, surface area for children's toys was estimated by assuming that a home has several items containing DCHP rather than one. Estimated values were based on EPA's professional judgment of the number and size of toys present in a bedroom. Low intensity use scenario was based on 5 small toys measuring 15 cm by 10 cm by 5 cm, the medium intensity use scenario was based on 20 medium toys measuring 20 cm by 15 cm by 8 cm, and high intensity use scenario was based on 30 large toys measuring 30 cm by 25 cm by 15 cm.

Table 2-5. Summary of Key Parameters for Inhalation and Dust Ingestion Exposure to DCHP 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]	Use Environment and Volume (m^3)[d]	Interzone Ventilation Rate (m^3/h)[d]
Children's toys (new)[f]	High	0.001	1.4	9.45	0.01	Bedroom	36	107.01
	Med	0.001		2.32				
	Low	0.001		0.28				

[a] See Section 2.1.1 for weight fraction sources and discussion.
[b] Used density of PVC from various sources, see *DCHP Draft Consumer Exposure Analysis Spreadsheet* (U.S. EPA, 2024b).
[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 a potential future application of the U.S. Consumer Product Safety Commission (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 five other phthalates and although DCHP is not currently part of this rule and the identified weight fractions did not exceed 0.1%, this consideration can assist future ruling decisions for DCHP.

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

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) 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.

While there has been considerable investigation of chemical migration rates of phthalates from plastic articles to saliva, rate measurements of DCHP specifically have not been extensively studied. However, chemical migration rates for dibutyl phthalate (DBP) are better characterized and may be used as a surrogate. The physical and chemical characteristics that are known to affect chemical migration rates are similar between DCHP and DBP, but the larger size, higher molecular weight, and lower solubility of DCHP as compared to DBP can be expected to result in a slower rate of migration through the polymer matrix and less partitioning to saliva for DCHP. Thus, using chemical migration rates of DBP to calculate the DCHP dose received during mouthing will provide a health protective estimate.

Chemical migration rates of phthalates to saliva may be measured by *in vitro* or *in vivo* methods. While 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 also 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 from a single assay condition were not considered adequate for estimating this parameter. The chemical migration rate of DCHP was estimated based on DBP chemical migration data compiled in a review published by the Denmark Environmental Protection Agency 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 saliva, as well as *in vivo* tests when such studies were available. The authors compiled 23 values from three studies (Danish EPA, 2010; Niino et al., 2003; Niino et al., 2001) for chemical migration rates of DBP from a variety of consumer goods measured with varying mouthing approaches, such as sucking, or chewing, or liking. These values were then subdivided into mild, medium, and harsh categories based on the mouthing approach used to estimate migration, but no data were found for DBP from assays using a medium condition. Reported values are shown in Table 2-6.

While there is considerable variability in the measured migration rates, there was not a clear correlation between weight fraction of DBP in the article and chemical migration rate. Mean values for chemical migration rates of DBP under mild and harsh assay conditions were used in the low and high exposure scenarios, respectively. The midpoint between the two values was used in the medium exposure scenario.

Table 2-6. Chemical Migration Rates Observed for DBP

Mouthing Approach	Migration Rate (µg/cm²/hr)[a]		
	Min	Mean (Standard Deviation)	Max
Mild	0.001	0.17[b] (0.24)	0.66
Harsh	1.17	48.5[b] (46.9)	144.8

[a] Information from Tables 17, 18, and 19 in (DTI, 2016)

[b] Selected values for assessment.

The DBP migration rates were used as a DCHP surrogate in this assessment. Due to lack of DBP medium mouthing approaches, EPA used the values reported for mild mouthing approaches.

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 standardized value of 10 cm² for mouthing surface area is commonly used in studies to estimate mouthing exposure in children (Danish EPA, 2010; Niino et al., 2003; Niino et al., 2001). 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 cm² was thus chosen for all mouthing exposure models for children.

Mouthing Duration

Mouthing durations were obtained from the *Exposure Factors Handbook*, Table 4-23 (U.S. EPA, 2011c) which provides mean mouthing durations for children between 1 month and 5 years of age, broken down by age groups expected to be behaviorally similar. Values are provided for toys, pacifiers, fingers, and other objects. For this assessment, only values for toys were used. The data provided in the Handbook was broken down into more age groups than CEM. 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 the mouthing duration in CEM, all relevant data in the *Exposure Factors Handbook* tables (U.S. EPA, 2011a) were considered together. The minimum value by item type within each age group was used in the low exposure scenario, maximum value was used in the high exposure scenario, and the mean value (average across the age groups provided in the Handbook) was used in the medium exposure scenario as shown in Table 2-7.

Table 2-7. Mouthing Durations for Children for Toys and Other Objects

	Estimated Mean Daily Mouthing Duration Values (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	1.0	28.3	39.2	23.07	39.2	22.9	1.0
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

	Estimated Mean Daily Mouthing Duration Values (min/day) [a]				Mouthing Durations for CEM Age Groups (min/day)		
Toy	15.3	16.6	11.1	15.8	16.6	14.7	11.1
Item Mouthed	Reported Age Group				CEM Age Group: Small Child 3–5 years		
	2 years	3 years	4 years	5 years	High Exposure Scenario	Med Exposure Scenario	Low Exposure Scenario
Toy	12.4	11.6	3.2	1.9	12.4	7.3	1.9

[a] Table 4-23 in *Exposure Factors Handbook* (U.S. EPA, 2011a)
[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 DCHP in air results in increased inhalation exposure. This may occur due to product formulation or use patterns that allow for higher emissions of DCHP to air and/or environment specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control DCHP emission rates from products in CEM 3.2 models are weight fraction of DCHP in the formulation, duration of product use, mass of product used, and frequency of use. Any increase in these parameters results in higher chemical exposure from product use.

Adhesive for small repairs products, assessed for dermal contact only (see Table 2-1), were not modeled with CEM. In the dermal exposure modeling the weight fraction data are used to confirm the presence of DCHP in the product but are not used as a model input (see Section 2.3). Dermal exposure assessments include high, medium, and low intensity use scenarios for each product using a range of modeling input parameters described in Section 2.3, such as dermal absorption, duration, frequency of the contact. Automotive adhesives were assessed for inhalation exposures in addition to dermal exposures using the available weight fraction ranges, and various CEM inputs for the high, medium, and low intensity use scenarios as shown in Table 2-8. CEM does not have default inputs for automotive adhesive products. As such, values for exposure scenario key parameters were based on professional judgement which incorporated information from product labels and information obtained from an informal survey of customer reviews on e-commerce sites. Product densities were taken from product specific technical specifications. A detailed description of derivations of other key parameter values used in CEM 3.2 models for automotive adhesives is provided below, and a summary of values can be found in Table 2-8. Note that articles not modeled for inhalation exposure are not included in Table 2-8.

Mass of Product Used

For automotive adhesives, the mass of product used was based on the reasonable assumption that the volume in which products are sold is adequate for the tasks they are intended for. For high exposure scenarios, it was assumed that the entire mass of the larger format product container, 210 ml, is used (Ford Motor Company, 2015). The low exposure scenario assumed that the entire mass of the smaller format product container,130 ml, was used (Ford Motor Company, 2015). Medium exposure scenario assumed the average of these two values.

Duration of Use

Automotive adhesives may be used for large projects, but the relatively short working time for these products limits the duration of use. As such, these products were modeled at use durations of 120, 60,

and 30 minutes for the high, medium, and low intensity use scenarios, respectively.

Frequency of Use

An informal survey of reviews posted by customers on e-commerce sites indicated that both product types are used primarily for large repair projects that require significant preparation and clean up. As such, it was assumed that individuals may use these products for one project on a yearly basis that may take 2 days to complete.

Table 2-8. 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 (Hr)	Product Mass Used (g)	Freq. of Use ($year^{-1}$)	Freq. of Use (day^{-1})	Use Environ. Volume (m^3) [c]	Air Exchange Rate, Zone 1 and Zone 2 (h^{-1}) [d]	Interzone Ventilation Rate (m^3/h) [d]
Automotive Adhesives	High	0.05	1.78	120	302.6	2	1	Garage; 90	0.45	108.98
	Med	0.035		60	151.3					
	Low	0.01		30	75.7					

[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 product SDS reported density value, (LORD Corporation, 2017) and (Ford Motor Company, 2015).
[c] Use environment was determined based on product manufacturer use description.
[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 DCHP, the interpretation of the dermal absorption data, and dermal absorption modeling efforts. The uncertainties associated with dermal absorption estimation are discussed in Section 4.

DCHP is a plasticizer, additive, and impurity in adhesives in relatively small amounts (see Section 2.1). In addition to polymer additive and plasticizer, DCHP can also be incorporated in the product formulation process as a phlegmatizer. Although inhalation and ingestion pathways were modeled using CEM (see Section 2.2), dermal modeling for liquid and solid products was done using the approach described below. For liquid and solid products, EPA used the steady-state permeability coefficient equations defined within the CEM model in a computational approach that bypassed the need for certain inputs required by CEM such as weight fractions and migration rates. For liquid products, the concentration of DCHP often exceeds its saturation concentration because DCHP molecules form weak chemical bonds with polymer chains in the product/article that favors migration out of the polymer. During direct dermal contact, DCHP can migrate to the aqueous phase available in the skin surface or be weakly bound to the polymer. The fraction of DCHP associated with polymer chains is less likely to contribute to dermal exposure as compared to the aqueous fraction of DCHP because the chemical is strongly hydrophobic. As such, use of the CEM model for dermal absorption, which relies on total concentration rather than aqueous saturation concentration, would greatly overestimate exposure to DCHP in liquid chemicals.

DCHP dermal specific data were not identified via the systematic review process. EPA used a dermal absorption modeling approach to characterize consumer dermal exposures to liquids or formulations and solids or articles containing DCHP (Section 2.3.2). Dermal exposures to vapors are not expected to be significant due to the extremely low volatility of DCHP, and therefore, are not included in the dermal exposure assessment of DCHP.

2.3.1 Flux-Limited Dermal Absorption Approach

When estimating dermal absorption of finite doses (*i.e.*, typically 1 to 10 mg/cm^2 for solids, (OECD, 2004)), 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 2-1.

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

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

Kissel (2011) indicates that high values of N_{derm} (>>1) suggest that supply of the material is in surplus, 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 absorptive flux should be utilized for estimating dermal absorption of flux-limited scenarios.

Typical consumer scenario dermal loadings range from 1 to 10 mg/cm^2 and exposure durations range from 1 to 24 hours. To estimate N_{derm} for consumer exposure to DCHP, EPA assumed a typical dermal loading estimate of 1 mg/cm^2 from the range of exposure durations, 24 hours, as it would yield the smallest N_{derm} value under consideration, and an average absorptive flux from 24 hours exposure of 2.44×10^{-5} mg/cm^2/h (see Section 2.3.2 for details on how this value was selected) as shown below.

$$N_{derm} = \frac{1\ mg/cm^2}{2.44 \times 10^{-5}\ \frac{mg}{cm^2 \cdot h} \times\ 24h} = 1.7 \times 10^3$$

Because N_{derm} >> 1 for a typical consumer dermal exposure scenario, it is shown that the absorption of DCHP is expected to be flux-limited even at finite doses, and that percent absorption should not be considered transferrable across exposure conditions.

2.3.2 Flux-Limited Dermal Absorption for Liquids and Solids

The first step in modeling dermal absorption through aqueous media is to estimate the steady-state permeability coefficient, K_p (cm/hr). EPA utilized the CEM K_p equation (U.S. EPA, 2023) to estimate the steady-state aqueous permeability coefficient of DCHP as 0.012 cm/hr. Next, EPA relied on Equation 3.2 from the *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual, (Part E: Supplemental Guidance for Dermal Risk Assessment)* (U.S. EPA, 2004), which characterizes dermal uptake (through and into skin) for aqueous organic compounds. Specifically, Equation 3.2 from U.S. EPA (2004), also shown in Equation 2-2 below, was used to estimate the dermally absorbed dose (DA_{event}, mg/cm^2) for an absorption event occurring over a defined duration (t_{abs}).

Equation 2-2. Dermal Absorption Dose During Absorption Event

$$DA_{event} = 2 \times FA \times K_p \times S_W \times \sqrt{\frac{6 \times t_{lag} \times t_{abs}}{\pi}}$$

Where:

DA_{event} = Dermally absorbed dose during absorption event t_{abs} (mg/cm^2)

FA = Effect of stratum corneum on quantity absorbed = 0.9 [see Exhibit A-5 of U.S. EPA (2004)]

K_p = Permeability coefficient = 0.012 cm/h (calculated using CEM (U.S. EPA, 2023))

S_w = Water solubility = 1.48 mg/L [see Table Apx B-1 in *Draft Physical Chemistry and Fate and Transport Assessment for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024e)

t_{lag} = $0.105\times10^{0.0056MW}$ = $0.105\times10^{0.0056*330.43}$ = 7.44 hours [calculated from A.4 of U.S. EPA (2004)]

t_{abs} = Duration of absorption event (hours)

By dividing the dermally absorbed dose (DA_{event}) by the duration of absorption (t_{abs}), the resulting expression yields the average absorptive flux. Figure 2-2 illustrates the relationship between the average absorptive flux and the absorption time for DCHP.

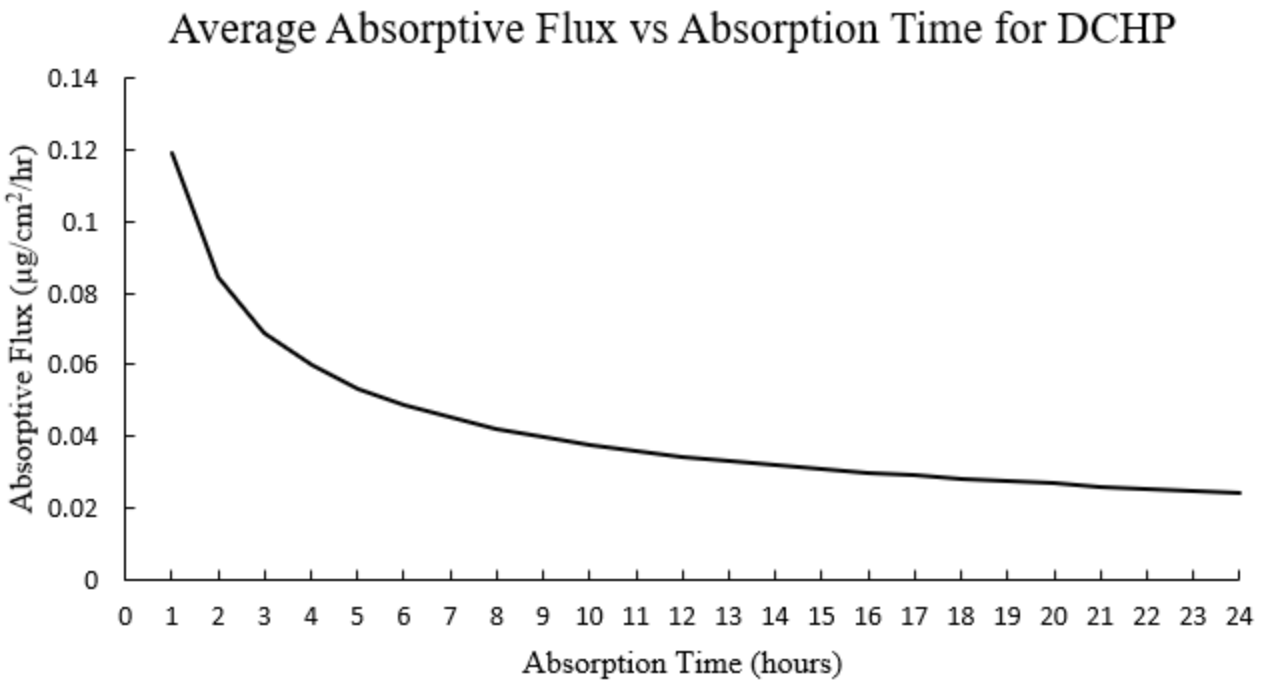


Figure 2-2. DCHP Average Absorptive Flux vs. Absorption Time

The neat form of DCHP is a solid, the concentrated formulations are paste-like, and any liquid containing DCHP has very low concentrations; therefore, it is reasonable to assume that flux-limited absorption of aqueous DCHP serves as a reasonable upper bound for the dermal absorption of DCHP across consumer scenarios. Dermal exposure to DCHP from solid articles is estimated using a flux-based approach. In this approach it was assumed that DCHP must first migrate into a thin film of moisture on the surface of the skin, and that solubility of DCHP by the moisture layer limits absorption. The flux-limited approach was used for both liquid and solid products. Aqueous flux-limited absorption values ranged from 1.19×10^{-4} to 2.43 mg/cm^2/h for 1 to 24 hours, see Figure 2-2. The estimation of average flux of aqueous material through and into the skin is dependent on the duration of absorption and must be determined based on the scenario under assessment. The 1 to 24 hours absorption time range captures the dermal exposure scenarios duration used in consumer scenarios. The dermal consumer exposure assessment scenarios consider a range of exposure durations that capture low, medium, and high intensity use scenarios and are described for each COU and product/article scenario in Section 2.3.3.

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. Key parameter values used in models are shown in Table 2-9. For contact area, professional judgement, based on product use descriptions from manufacturers and article 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 *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). The subsections under Table 2-9 provide details on assumptions used to derive other key parameters. Calculations, sources, input parameters and results are also available in *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2024a). Acute and chronic dose calculations and equations are

summarized in Appendix A.4.

Table 2-9. Key Parameters Used in Dermal Models

Product	Scenario	Duration of Contact (min)	Chronic Frequency of Contact (year $^{-1}$)	Acute Frequency of Contact (day^{-1})	Flux [a] (mg/cm^2/h)	Contact Area
Adhesives for Small Repairs	High	60	52	1	1.21E−04	10% of Hands (some fingers)
	Medium	30			1.70E−04	
	Low	15			2.41E−04	
Automotive Adhesives	High	120	2	1	8.52E−05	10% of Hands (some fingers)
	Medium	60			1.21E−04	
	Low	30			1.70E−04	
Children's Toys	High	137	365	1	7.97E−05	Inside of two hands (palms, fingers)
	Medium	88			9.95E−05	
	Low	24			1.91E−04	
Outdoor Seating	High	240	52	1	6.03E−05	Inside of two hands (palms, fingers)
	Medium	120			8.52E−05	
	Low	60			1.21E−04	
Small Articles with Potential for semi-routine contact	High	120	365	1	8.52E−05	Inside of one hand (palms, fingers)
	Medium	60			1.21E−04	
	Low	30			1.70E−04	

[a] See Section 2.3.2 and *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2024a).

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. As such, 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 (adhesives for small repairs), it was assumed that use would be relatively quick, though project size may vary. As such, durations for high, medium, and low exposure scenarios were assumed to be 60, 30, and 15 minutes.

For articles that do not include duration of use as an input in CEM, professional judgement was used to select the duration of use/article contact for the low, medium, and high exposure scenario levels. For children's toys, data was obtained from the Children's Exposure Factors Handbook, Table 16-26. Reported values for playtime for children under 15 years ranged from 24 min/day to 137 min/day, with a mean value of 88 min/day; these values were used in the low, high, and medium exposure scenarios. The

playtime duration used for children under 15 years was also used for children 16 to 20 years due to lack of playtime duration information for this age range and as conservative assumption that can be further refined should risk be identified in the risk characterization stage of this assessment; see Section 4 of the *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). For concrete coatings on outdoor seating, a maximum duration of 240 minutes was selected to represent attendance of sporting events. Shorter durations of 120 and 60 minutes were selected for medium and low scenarios to represent shorter events.

In addition to the scenarios for dermal exposure to DCHP from specific articles, a scenario was modeled in which consumers may have semi-routine contact with one or more small items containing DCHP. An outline of materials which might be captured in this scenario is provided in Section 2.1. While 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 uncertainty around items with DCHP content, EPA considers it reasonable to assume that an individual could have significant daily contact with some combination of 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 adhesives used for small repairs and projects, it was assumed that individuals might be in contact once per week.

For articles, assumptions about frequency of use were made based on professional judgement based on one contact per event duration as a conservative screening approach, further refinement is considered at the risk calculation stage, see *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). For articles which are expected to be used on a routine basis, such as children's toys, and small articles with semi-routine contact potential, use was assumed to be once per day every day. For concrete coatings used on outdoor seating, it was assumed that an event was attended once per week.

2.4 Key Parameters for Intermediate Exposures

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 2-8 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 2-10. Short-Term Event per Month and Day Inputs

Product	Events Per Day[a]	Events Per Month[a]
Construction Adhesive for Small Scale Projects	3	4
Construction Sealant for Large Scale Projects	1	3
Lacquer Sealer (Non-spray)	1	2
Lacquer Sealer (Spray)	1	2
[a] Events per day and month values determined using professional judgement based on manufacturer product description use.		

3 CONSUMER EXPOSURE MODELING RESULTS

This section summarizes the dose estimates from inhalation, ingestion, and dermal exposure to DCHP in consumer products and articles. Exposure via the inhalation route occurs from inhalation of DCHP gas-phase emissions or when DCHP 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 DCHP migrates from a product or article to dust or partitions from gas-phase to dust.

3.1 Acute Dose Rate Results, Data, Patterns, and Conclusions

The *DCHP Draft Consumer Risk Calculator* (U.S. EPA, 2024c) summarizes all the high, medium, and low acute dose rate results for all lifestages from CEM modeling for inhalation and ingestion exposures, and 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 for discussion about 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 DCHP by proximity to the use of the product via inhalation of gas-phase emissions or suspended dust. Some product scenarios were assessed for bystanders for children under 10 years and as users older than 11 years because the products were not targeted for very young children (<10 years). In instances where a lifestage could reasonably be either a product user or bystander, the inputs for a user were selected because that scenario would result in larger exposure doses as compared to a bystander. The main purpose of *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) is to summarize acute dose rate results (and risk estimates), show both which products or articles did not have a quantitative result and which results are used for bystanders. Data patterns are illustrated in figures in this section with a summary and descriptions of the patterns by exposure route and population or lifestage.

Figure 3-1 through Figure 3-4 show acute dose rate data for all products and articles modeled for all lifestages. The figures show average dose rate (ADR) estimated from exposure via inhalation, ingestion (aggregate of mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact. Among the younger lifestages (*i.e.*, <5 years), exposures are driven by ingestion via mouthing, while inhalation and dermal patterns are similar to other lifestages for these same exposure pathways. For children older than 6 years, teens, and adults, dermal contact was a strong driver of exposure to DCHP—higher than 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 DCHP 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 designation as a product user or bystander; behavioral differences such as mouthing durations, hand to mouth contact times, and time spent on the floor; and dermal contact expected from touching specific articles, which may not be appropriate for some lifestages. Figures and observations specific to each lifestage are below.

Of all scenarios evaluated, for all products and articles, and all lifestages (see Figure 3-2 to Figure 3-4), infants, toddlers, and preschoolers have the highest dose of DCHP from a single exposure route. Specifically, this is due to the DCHP dose from ingestion of settled and suspended dust and direct

mouthing. For articles assessed for mouthing, such as toys, exposure from mouthing is expected to have a larger impact in the overall ingestion dose compared to ingestion of settled and suspended dust. Mouthing tendencies decrease or cease entirely for children 6 to 10 years old (Figure 3-2). Articles that were not assessed for mouthing were assessed for ingestion of settled and suspended dust, for which the settled dust exposures tend to be larger than ingestion from suspended dust (*Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c)).

Infants, Toddlers, and Preschoolers, (Birth to 5 Years)

Figure 3-1 show all exposure routes for infants less than one year old, toddlers 1 to 2 years old, and preschoolers 3 to 5 years old. Dose result patterns were very similar for the same products or articles and routes of exposure across these three lifestages, see *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c). EPA averaged the three lifestages into one dose result for all in Figure 3-1. Acute dose for the ingestion route is the sum of all ingestion scenarios (mouthing, suspended dust, and surface dust). Inhalation exposure from toys considers dust collected on surfaces and settled dust from a relatively large area that contains multiple toys collecting dust with DCHP.

For infants through 5-year-olds, ingestion resulted in the highest ADR followed by the dermal and then inhalation routes. The ingestion ADR for high and medium intensity use are higher than the full range of the dermal ADR values for all items, while the ingestion low intensity ADR is three orders of magnitude lower than the dermal low intensity ADR. Dermal exposure differences among items and high to low intensity use scenarios are driven mainly by the exposure duration and frequency, and exposed dermal surface area. The dose from coated outdoor seating and children's toys were similar and about an order of magnitude higher than for articles with potential for semi-routine contact mainly due to longer contact durations and frequencies. Notably, the contact duration (see Table 2-9) for coated outdoor seating was longer than that for children playing with toys. The outdoor seating high to low intensity use scenarios considered plausible ranges of outdoor activities like sporting events and concerts, and plausible skin contact area; however, EPA recognizes that continuous contact for the duration of the event may be an overestimation. The children's toys scenario considers total contact duration in one day with single toys rather than assuming frequency (how many times a child plays with a toy in a day) of contact in a day with a single toy, which would have introduced larger uncertainty to the ADR calculation. See Table 2-9 for dermal modeling parameters per products and articles.

Inhalation doses of automotive adhesives for the infant, toddler, and preschooler lifestages represent bystander exposures because these lifestages are not expected to be users of these product types. The inhalation doses from automotive adhesive products are overall higher than the inhalation doses from indoor inhalation of suspended dust from children's toys. The differences are driven by increased DCHP weight fractions in automotive adhesives (see Table 2-8) as compared to children's toys (see Table 2-5).

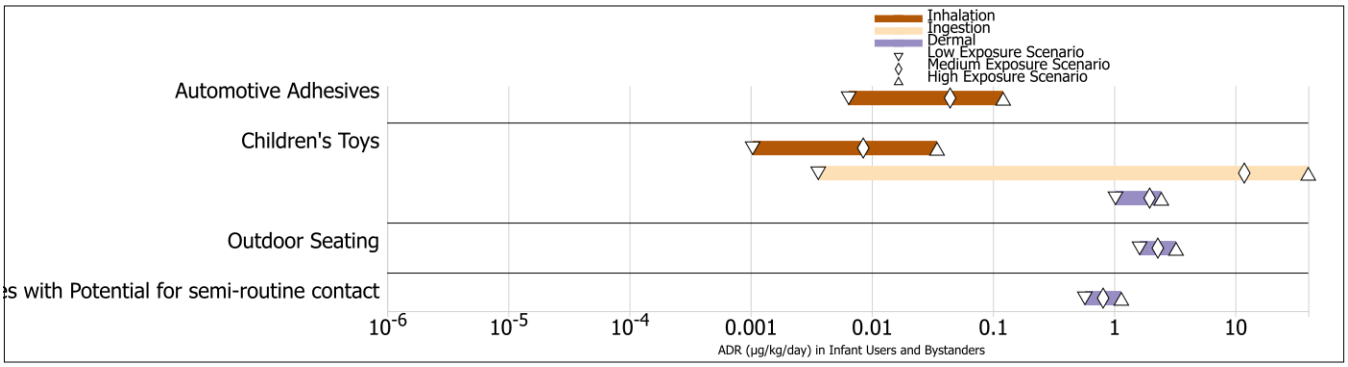


Figure 3-1. Acute Dose Rate for DCHP from Ingestion, Inhalation, and Dermal Exposure Routes in Infants Aged <1 Year, Toddlers Aged 1–2 Years, and Preschoolers Aged 2–5 Years

Note: Preliminary figure, horizontal axis label is for infants, toddlers, and preschoolers. Cutoff vertical label is for articles with potential for semi-routine contact.

Middle Childhood, Young Teens, Teenagers, Young Adults, and Adults (6–21 and >21 Years)

Figure 3-2 through Figure 3-4 show all exposure routes for children ages 6 to adults above 21 years old. Dose result patterns were very similar for the same products or articles and routes of exposure across these five lifestages; see *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) doses per lifestage. However, because some products were not targeted for all lifestages, EPA only averaged the lifestages ADR values when the lifestages considered the same products and articles into one dose result for all in Figure 3-2 through Figure 3-4. Children 6 to 10 years old Figure 3-2 and adults older than 21 years, Figure 3-4, stand alone because children 6 to 10 years are not targeted to use or have bystander exposures from automotive adhesives and adhesives for small repairs and adults lack dermal exposures to toys. Children 11 to 15 years and teenagers and young adults aged 16 to 20 years were averaged because the ADR results were comparable and the same products and articles were assessed for these two lifestages in Figure 3-3.

The ADR for the inhalation and ingestion exposure routes cover a larger range, see high to low intensity use ADR values, than the dermal route for the same product and article categories such as for adhesives. This wider range for inhalation and ingestion ADR values is primarily due to a wider distribution of weight fraction (see Table 2-5 and Table 2-8) values. Weight fraction inputs are used in the ingestion and inhalation ADR CEM modeling, but not in the dermal calculations.

For all lifestages from age 6 through adult, the ADR from the dermal exposure route represents the highest dose, followed by the inhalation and ingestion routes, for all articles and products. Dermal exposure differences among article and product scenarios are driven mainly by the exposure duration and frequency and exposed skin surface area. Dermal exposure resulted in the highest doses overall. Coated outdoor seating dermal doses are similar to children's toys, then articles with potential for semi-routine contact, and finally the adhesive products. The contact duration for toys is slightly shifted than for outside seating; thus, dermal doses from exposure to toys and outside seating are considered similar. Dermal doses from exposure to children's toys are similar for all lifestages from 6 to 20 years (see Figure 3-1 to Figure 3-3). The playtime duration used for children under 15 was also used for children 16 to 20 years due to lack of playtime duration information for this age group and as conservative assumption that can be further refined should risk be identified in the risk characterization stage of this draft assessment; see Section 4 of the *Draft Risk Evaluation for Dicyclohexyl Phthalate (DCHP)* (U.S. EPA, 2024f). Dermal doses for articles with potential for semi-routine contact are larger than for adhesives mainly due to differences in exposure duration per event and a smaller surface area in contact. See Table 2-9 for dermal modeling parameters per scenario.

Inhalation exposure as a bystander for lifestages above 10 years of age was not targeted for adhesives and sealants. Children above 10 years can use these products in a similar capacity as adults during do-it-yourself (DIY) projects and as bystanders; therefore, this lifestage was modeled as a user of the product rather than a bystander. Users and bystanders have similar inhalation exposure doses for automotive adhesives. Inhalation of suspended dust from toys is similar across lifestages.

Ingestion via mouthing is significantly lower which is expected due to a decrease or cessation in mouthing behavior. Mouthing tendencies decrease significantly for theses lifestages; thus, most scenarios do not estimate exposure via mouthing. Ingestion of settled dust is the only ingestion pathway considered outside of mouthing for children's toys, which suggests that indoor dust ingestion and inhalation from dust collected on children's toys can contribute to DCHP exposures. However, these are multiple orders of magnitude lower than dermal exposures.

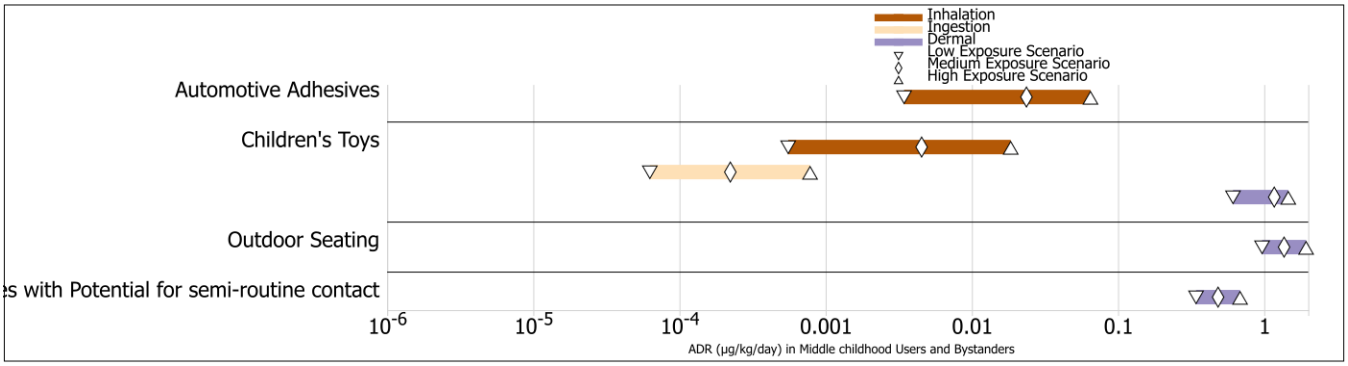


Figure 3-2. Acute Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes for Middle Childhood Ages 6–10 Years

Note: Cutoff vertical axis label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

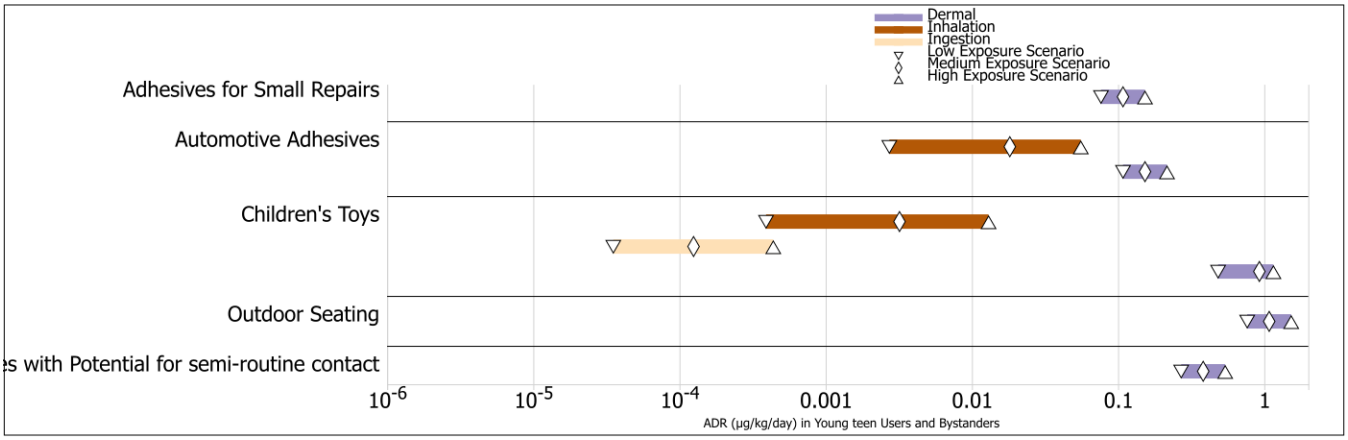


Figure 3-3 Acute Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes for Young Teens Aged 11–15 Years and Teenagers and Young Adults Aged 16–20 Years

Note: Horizontal axis label is for young teens, teenagers, and young adults. Cutoff vertical label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

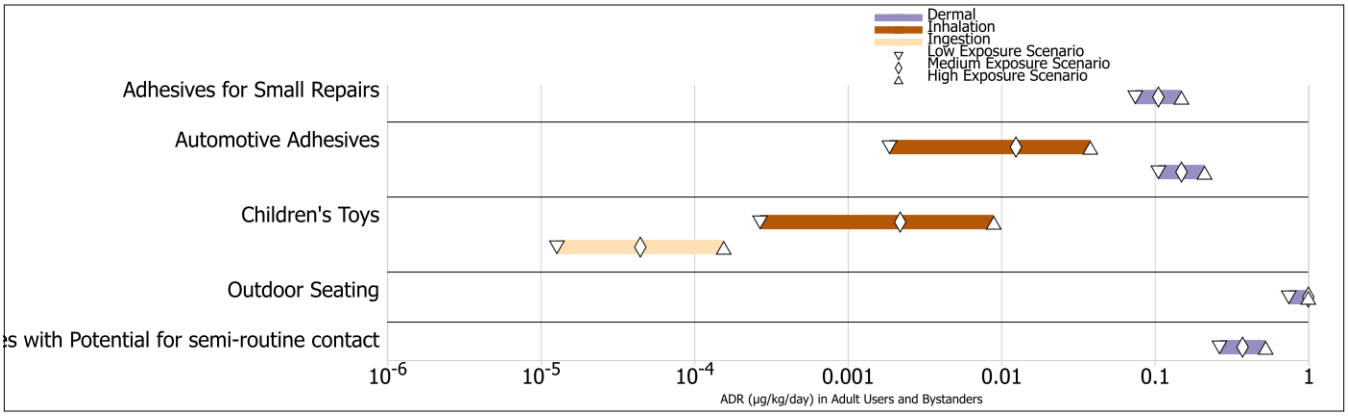


Figure 3-4. Acute Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes in Adults Older than 21 Years

Note: Cutoff vertical axis label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

3.2 Intermediate Average Daily Dose Conclusions and Data Patterns

The *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) summarizes all the intermediate dose results for high (H), medium (M), and low (L) intensity use scenarios based on modeling in CEM and outside of CEM (dermal only) for all exposure routes and lifestages. Only one product example under the Adhesives and sealants COU was a candidate for intermediate exposure scenarios. Intermediate exposure scenarios were built for products used between 30 and 60 days, and EPA used 30 days or approximately 1 month for product use. 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 automotive adhesives qualified to be used in intermediate scenarios. Based on manufacturer use description and professional judgement/assumption, these products may be used repeatedly within a 30-day period depending on projects. Infants to middle 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 these lifestages can use automotive and construction adhesives in home renovation projects or other hobbies. Infants to middle childhood lifestages are considered bystanders when these products are in use and are exposed via inhalation. Direct dermal contact has a larger dose than inhalation for the uses during application. See Figure 3-5 and Figure 3-6 for intermediate dose visual representations.

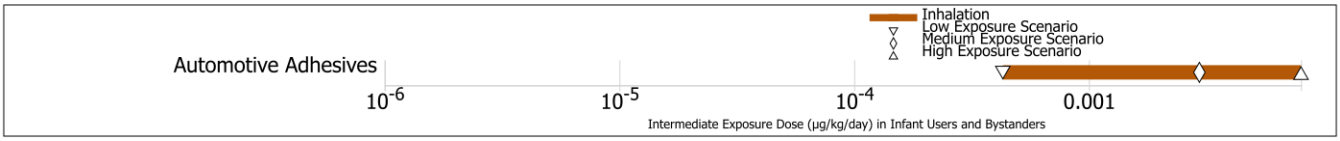


Figure 3-5. Intermediate Dose Rate for DCHP from Inhalation Exposure Route in Infants Aged <1 Year to Middle Childhood Aged 6–10 Years

Note: Horizontal axis label is for infants, toddlers, preschoolers, and middle childhood. Figure will be corrected in the finalized risk evaluation.

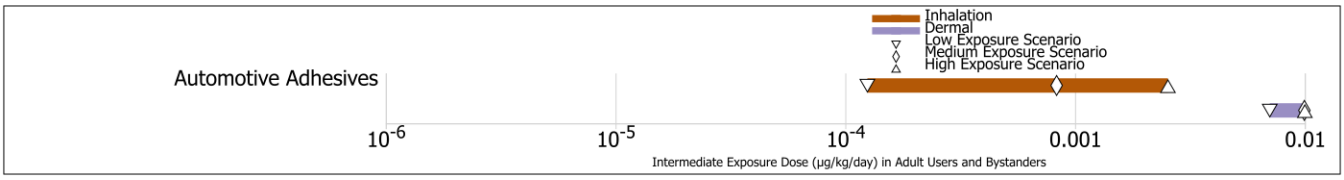


Figure 3-6. Intermediate Dose Rate for DCHP from Inhalation Exposure Route Young Teens Aged 11–15 Years to Adults Older than 21 Years

Note: Horizontal axis label is for young teens, teenagers, young adults, and adults. Figure will be corrected in the finalized risk evaluation.

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

The *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) summarizes all the high (H), medium (M), and low (L) intensity use 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 (-). Dose results applicable to bystanders are highlighted in yellow. Bystanders are people that are not in direct use or application of the product/article but can be exposed to DCHP by proximity to the use of the product/article via inhalation of gas-phase emissions or suspended dust. Some product/article scenarios were assessed for bystanders for children under 10 years and as users for older than 11 years because the products were not targeted for very young children (<10 yrs). People older than 11 years can also be bystanders; however, the user scenarios had inputs that would result in larger exposure doses. The main purpose of *Draft Consumer Risk Calculator (DCHP)* (U.S. EPA, 2024c) is to summarize chronic daily dose results (and risk estimates), show which products or articles did not have a quantitative result, and which results are used for bystanders.

Data patterns are illustrated in figures and summary descriptions of the patterns by exposure route and population or lifestage are summarized in this section. The following set of figures (see Figure 3-7 to Figure 3-10) show chronic average daily dose data for all products and articles modeled in all lifestages. For each lifestage, figures are provided which show CADD estimated from exposure via inhalation, ingestion (aggregate of mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact. The chronic average daily dose figures resulted in similar overall data patterns as the acute doses for inhalation and ingestion, but not dermal exposures. Outdoor seating dermal doses are lower for chronic because the frequency of use is less throughout a year (*i.e.*, once a week in a year), while contact with children's toys is the largest dermal dose because the frequency of contact is every day for a year. Articles with potential for routine contact dermal dose is larger than outside seating because frequency of contact is larger per year, but smaller than the dermal doses from toys due to smaller use durations per event. See Table 2-9 for dermal modeling parameters per scenario.

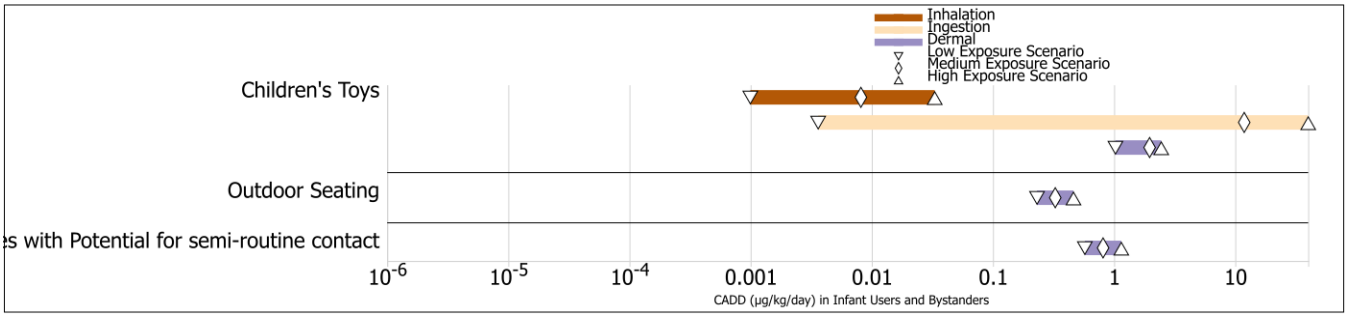


Figure 3-7. Chronic Dose Rate for DCHP from Ingestion, Inhalation, Dermal Exposure Routes in Infants Aged <1 Year, Toddlers Aged 1–2 Years, and Preschoolers Aged 3–5 Years

Note: Horizontal axis label is for infants, toddlers, and preschoolers. Cutoff vertical label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

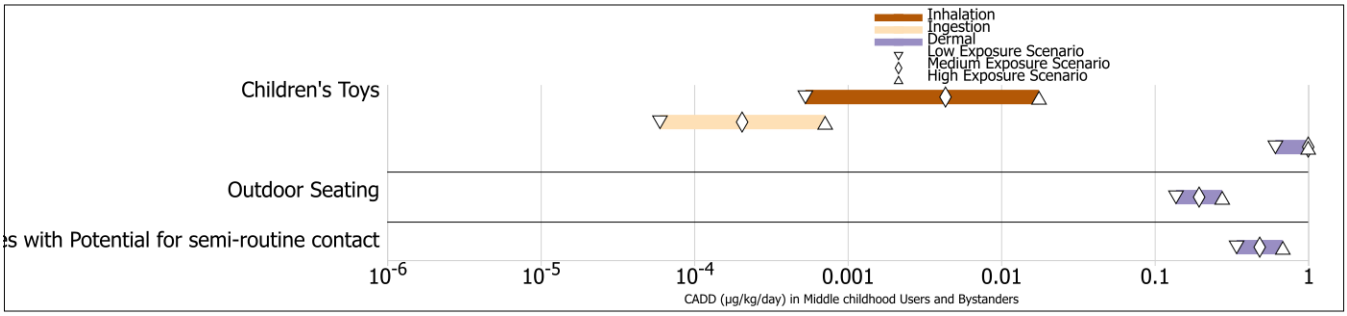


Figure 3-8. Chronic Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes for Middle Childhood Ages 6–10 Years

Note: Cutoff vertical axis label is for articles with potential for semi-routine contact. Figure will be corrected in finalized risk evaluation.

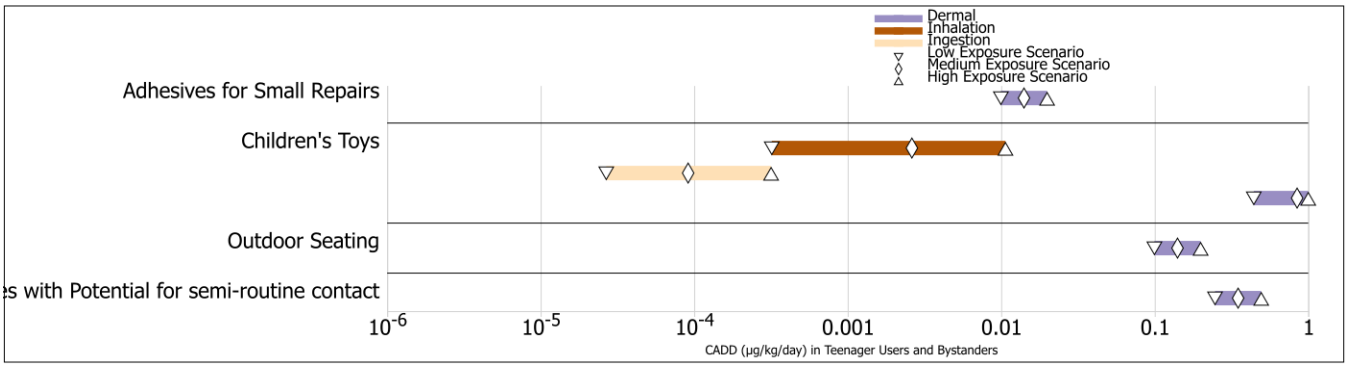


Figure 3-9. Chronic Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes for Young Teens Aged 11–15 Years and Teenagers and Young Adults Aged 16–20 Years

Note: Horizontal axis label is for young teens, teenagers, and young adults. Cutoff vertical label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

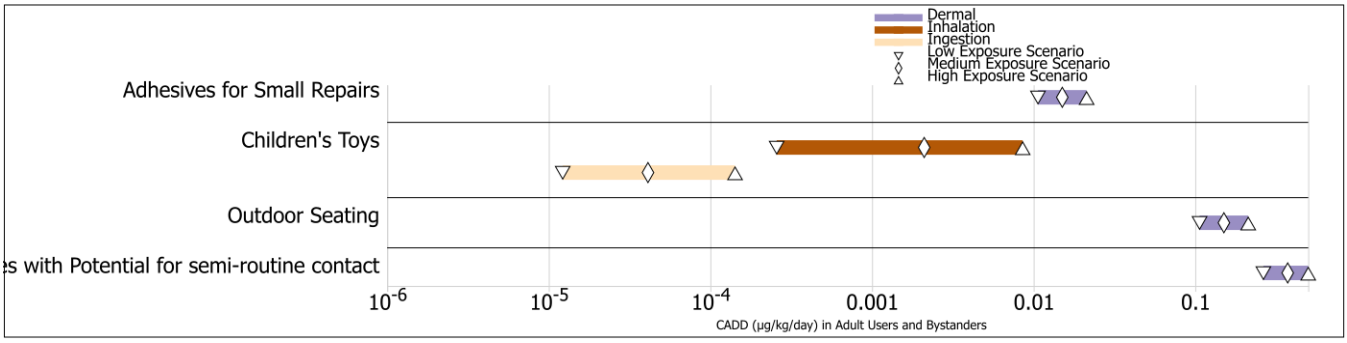


Figure 3-10. Chronic Dose Rate of DCHP from Ingestion, Inhalation, and Dermal Exposure Routes in Adults Older than 21 Years

Note: Cutoff vertical axis label is for articles with potential for semi-routine contact. Figure will be corrected in the finalized risk evaluation.

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 consumer exposure assessment, Table 2-1, to reconstruct major indoor sources of DCHP in dust and obtain COU and product specific exposure estimates for ingestion and inhalation of dust. Other non-residential environments can have these articles, such as daycares, offices, malls, schools, and other public indoor spaces. The indoor consumer articles exposure scenarios were modeled with stay-at-home parameters that consider use patterns similar 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 as a health protective upper-bound scenario.

The monitoring data considered are from residential dust samples from U.S.-based studies. Measured DCHP concentrations were compared to evaluate consistency among data sets. EPA used three U.S. monitoring studies to generate an estimate of overall DCHP exposure from ingestion of indoor dust but a monitoring and modelling comparison was not performed due to low confidence in the monitoring data as an adequate U.S. population representative. The monitoring studies and assumptions made to estimate exposure are described in Section 4.1 and Section 4.2.

4.1 Indoor Dust Monitoring Data

During systematic review, a total of 13 studies containing potential indoor dust monitoring data for DCHP were identified. Data from the U.S. and multiple Asian and European countries were identified. Out of these studies, three were selected because they are primary studies conducted in the United States, reported sampling and analytical methods, and measured dust in a home, offices, or other indoor environments that are representative of the U.S. general population. Data from other countries, such as China, India, Kuwait, Vietnam, and Turkey, 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. Data from German studies would be an acceptable surrogate, but the reported data is mainly from non-residential locations or targeting non-TSCA sources such as personal care products.

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. Samples were collected by slowly and lightly drawing a vacuum crevice tool just above the surface of rugs, upholstery, wood floors, windowsills, ceiling fans, and furniture in each room for 45 to 90 minutes.

In Guo and Kannan (2011), 33 settled dust samples were collected from Albany, New York, between December 2007 and January 2008, as well as during May 2010. Samples contained particles from carpet flooring and were taken by vacuum cleaner bags of several homes.

In Dodson et al. (2015), 49 settled dust samples were collected from homes in California during 2006. Samples were collected by slowly dragging a vacuum 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 about 30 minutes.

DCHP measurements from the three studies are provided in Table 4-1.

Table 4-1. Detection and Quantification of DCHP in House Dust from Three Studies

Study	Indoor Environment[a]	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	6	1.86[b]	NR[c]	0.569	5.38	1.62	NR	100
Guo and Kannan (2011)	Home	33	NR	ND[d]	ND	0.3	NR	NR	18
Dodson et al. (2015)	Home	49	NR	ND	ND	13	NR	7.4[b]	16

[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 4-1
[c] NR, not reported.
[d] ND, not detected.

Available DCHP dust monitoring data is very limited, and therefore has limitations in terms of its representativeness of actual dust concentrations in U.S. homes. Given the unknown effects of the identified uncertainties within the monitoring data, EPA calculated the ingestion doses (Section 4.2) from monitoring data but no further analysis or use of the monitoring data should be expected in this assessment.

4.2 Indoor Dust Monitoring Ingestion Dose Results

To estimate DCHP dust ingestion, the mean ingestion from the measured concentrations for residential (homes) in Table 4-1 was used (see table note b). Studies that did not report means were not used in the calculation and only residential values were used. The same equation was used to calculate the 95th percentile.

EPA obtained U.S. sources for dust ingestion rate and body weights to conduct allometric exposure estimates. 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. Geometric mean and 95th percentile dust ingestion rates for ages 0 to 21 years were taken from Özkaynak et al. (2022) to estimate DCHP ingestion dose in dust (Table 4-2). The geometric mean was used as the measure of central tendency because the distribution of ingestion intakes is skewed.

Özkaynak et al. (2022) did not estimate dust ingestion rates for ages beyond 21 years. However, the *Exposure Factors Handbook* (U.S. EPA, 2011a) 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 Handbook, estimates were calculated for DCHP ingestion doses for 21 to 80 or more years (Table 4-3).

DCHP dust ingestion was calculated according to Equation 4-1 for two scenarios, (1) mean (geometric mean [GM] dust inhalation, median DCHP concentration in dust); and (2) high-end (dust inhalation, 95th percentile DCHP concentration in dust). The mean from Rudel et al. (2001) and 95th percentile from Dodson et al. (2015) were used in the calculation for DCHP ingestion dose. Body weights representative of the U.S. population were taken from the *Exposure Factors Handbook* (U.S. EPA,

2011b).

Equation 4-1. Calculation of DCHP Ingestion Dose

$$DCHP\ dose\ \left(\frac{\mu g\ DCHP}{kg\ bw \times day}\right) = \frac{Dust\ ingestion\ \left(\frac{mg\ dust}{day}\right) \times Dust\ concentration\ \left(\frac{\mu g\ DCHP}{g\ dust}\right)}{kg\ bw} \times \frac{1\ g}{1000\ mg}$$

Estimates of DCHP 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 DCHP Dust Ingestion Per Day from Monitoring, Ages 0–21 Years

Age Range		0–<1 m	1–<3 m	3–<6 m	6 m–<1 y	1–<2 y	2–<3 y	3–<6 y	6–<11 y	11–<16 y	16–<21 y
Dust ingestion (mg/day) [a]	GM	3.6	3.5	4.1	5.4	8	8.9	10	12	15	16
	95th Percentile	7.1	5.8	6.1	8.0	13	14	14	17	22	25
Body weight (kg) [b]		4.8	4.8	5.9	7.4	9.2	11	14	19	32	57
DCHP Ingestion (µg/kg-day)	Central tendency (1.86 µg DCHP/g dust)	5.6E−3	4.4E−3	4.1E−3	4.3E−3	5.2E−3	4.8E−3	4.0E−3	2.8E−3	2.0E−3	5.6E−3
	High end (7.4 µg DCHP/g dust)	5.6E−3	4.4E−3	4.1E−3	4.3E−3	5.2E−3	4.8E−3	4.0E−3	2.8E−3	2.0E−3	1.7E−3

m = month(s); y = year(s)
[a] From Özkaynak et al. (2022)
[b] From U.S. EPA (2011b)

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

Age Range		21–<30 y	30–<40 y	40–<50 y	50-<60 y	60-<70 y	70-<80 y	>80 y
Dust ingestion (mg/day)[a]	GM	16	16	16	16	14	13	12
	95th Percentile	21	21	21	21	18	17	16
DCHP Ingestion (µg/kg-day)	Central tendency (1.86 µg DCHP/g dust)	1.7E−3	1.5E−3	1.5E−3	1.4E−3	1.4E−3	1.3E−3	1.2E−3
	High end (7.4 µg DCHP/g dust)	1.5E−3	1.5E−3	1.4E−3	1.4E−3	1.3E−3	1.2E−3	1.3E−3
Body weight (kg)[b]		78	78	81	84	83.4	82.6	76.4

y = year(s)
[a] From Özkaynak et al. (2022) (rates for 16-21y)
[b] From U.S. EPA (2011b)

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. 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 DCHP 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 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 the assessor is making the best scientific assessment possible in the absence of complete information and there are additional uncertainties that may need to be considered. Table 5-1 summarizes the overall uncertainty per COU, and a discussion of rationale used to assign the overall uncertainty. The subsections ahead of the table 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, see Table 5-1. 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 lean 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 limited for weight fractions of DCHP in consumer goods. EPA obtained DCHP weight fractions in various products and articles from material safety sheets, databases, and existing literature (Section 2.1). Where possible, EPA 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 high, medium, and low 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, **robust** for products/articles with more than one source and **slight** for articles with only one source with unconfirmed content or little understanding on how the information was produced.

Product Use Patterns

Consumer use patterns like frequency of use, duration of use, and methods of application are expected to differ. Where possible, high, medium, and low 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 DCHP emissions to the environment. For each article modeled for inhalation exposure, low, medium, and high estimates for surface area were calculated (Section 2.2.3.1). For small items which might be expected to be present in a home in significant quantities, such as children's toys, multiple items of the same type were aggregated to calculate the cumulative surface area for each type of article in the indoor environment. Overall, confidence in surface area is **robust** for articles like toys 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 Consolidated Human Activity Database (CHAD). 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 data 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 per session, for 20 sessions (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 6-9 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 was not limited to soft plastic items likely to contain significant plasticizer content. In another study, 169 children aged 3 months to 3 years were monitored by trained observers for 12 sessions at 12 minutes each (Greene, 2002). They reported mean mouthing durations ranging from 0.8 to 1.3 minutes per day for soft plastic toys and 3.8 to 4.4 minutes per day for other soft plastic objects (except pacifiers). Thus, it is likely that the mouthing durations used in this assessment provide a health protective estimate for mouthing of soft plastic items likely to contain DCHP.

Modeling Tool

Confidence in the model used considers whether the model has been peer review, as well as whether it is being applied in a manner appropriate to its design and objective. The model used, CEM 3.2, has been peer review (ERG, 2016), is publicly available, and has been applied in the manner intended by estimating exposures associated with uses of household products and/or articles. This 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 DCHP

Experimental dermal data was identified via the systematic review process to characterize consumer dermal exposures to liquids or mixtures and formulations containing DCHP, see Section 2.3.1. EPA has moderate understanding of the scientific evidence and the uncertainties. The determination of uncertainties supporting scientific evidence is reasonably adequate to characterize exposure estimates, although the approaches likely overestimate dermal exposures. EPA has a **slight** confidence in the dermal exposure to liquid and solid products or articles modeling approach.

A source of uncertainty regarding the dermal absorption of DCHP from products or formulations stems from the varying concentrations and co-formulants that exist in products or formulations containing DCHP. For purposes of this risk evaluation, EPA assumes that the absorptive flux of DCHP serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all liquid products or formulations, and that the modeled absorptive flux of aqueous DCHP serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all solid products. However, dermal contact with products or formulations that have lower concentrations of DCHP may exhibit lower rates of flux since 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 DCHP would result in decreased or increased dermal absorption. Based on the available dermal absorption data for DCHP, EPA has made assumptions that result in exposure assessments that are the most human health protective in nature.

Lastly, EPA notes that there is uncertainty with respect to the modeling of dermal absorption of DCHP from solid matrices or articles and liquid products and formulations. Because there were no available data related to the dermal absorption of DCHP from solid matrices or articles and liquid products, EPA has assumed that dermal absorption of DCHP from solid objects would be limited by aqueous solubility of DCHP. Therefore, to determine the maximum steady-state aqueous flux of DCHP, EPA utilized the Consumer Exposure Model (CEM) (U.S. EPA, 2023) to first estimate the steady-state aqueous permeability coefficient of DCHP. The estimation of the steady-state aqueous permeability coefficient within CEM (U.S. EPA, 2023) is based on a quantitative structure-activity relationship (QSAR) model presented by ten Berge (2009), which considers chemicals with log(K_{ow}) ranging from -3.70 to 5.49 and molecular weights ranging from 18 to 584.6. The molecular weight of DCHP falls within the range suggested by ten Berge (2009), as does the log(K_{ow}) of DCHP. Therefore, there is a low to medium (due to assumptions used in migration of DCHP from solid to aqueous media) uncertainty regarding the accuracy of the QSAR model used to predict the steady-state aqueous permeability coefficient for DCHP.

Modeling Parameters for DCHP Chemical Migration

DCHP is considered a data poor chemical with respect to migration of chemical to saliva, meaning specific empirical information is scarce. Data were lacking for key parameters to describe the dynamic physical behavior of DCHP that will influence exposure, particularly the chemical migration rate from articles mouthed. To address this data gap, a scientifically informed approach was adopted, wherein values from analogous chemicals sharing comparable physical and chemical properties were leveraged as surrogates. For the mouthing exposure assessment, EPA used DBP as a surrogate. Based on the DBP available empirical evidence and the relative similarity in physical chemical characteristics, such as the larger size, higher molecular weight, and lower solubility of DCHP as compared to DBP can be expected to result in a slower rate of migration through the polymer matrix and less partitioning to saliva for DCHP, facilitated the estimation of chemical migration rate.

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 among similar items due to variations in chemical makeup and polymer structure. As such, an effort was made to choose DBP (DCHP selected surrogate) migration rates likely to be representative of broad classes of items that make up consumer COUs produced with different manufacturing processes and material formulations. The physical and chemical characteristics of DCHP and DBP known to affect chemical migration rates are similar, but the larger size, higher molecular weight, and lower solubility of DCHP as compared to DBP can be expected to result in a slower rate of migration through the polymer matrix and less partitioning to saliva for DCHP. Thus, using chemical migration rates for DBP to calculate the DCHP dose received during mouthing will provide a health protective estimate.

Table 5-1. Weight of Scientific Evidence Summary Per Consumer COU

Consumer COU Category and Subcategory	Weight of Scientific Evidence	Overall Confidence
Adhesives and sealants	Two different scenarios were assessed under this COU for products with differing use patterns for which each scenario had varying number of identified product examples (in parenthesis): adhesives for small repairs (2) and automotive adhesives (3). The two scenarios and the products within capture the variability in product formulation and are represented in the high, medium, and low intensity use estimates. The overall confidence in this COU inhalation exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. For dermal exposure EPA used a dermal flux approach, moderate was selected for this approach because the moderate uncertainty in the partitioning from product to skin and subsequent dermal absorption is not well characterized or confirmed with experimental results. However, other parameters like frequency and duration of use, and surface area in contact are well understood and representative, making the overall confidence in a health protective estimate moderate.	Inhalation – Robust Dermal – Moderate
Plasticizer in other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	One scenario was assessed under this COU. The scenario considered multiple articles and routine dermal contact with similar use patterns. The scenario for small articles of routine dermal contact was assessed for dermal exposures only because inhalation and ingestion would have low exposure potential due to the small surface area of the articles. The articles with routine contact scenario considered multiple input parameters used in the high, medium, and low intensity use scenarios. The overall confidence in this COU for the dermal exposure assessment is moderate. The dermal absorption estimate assumes that dermal absorption of DCHP from solid objects would be limited by the aqueous solubility of DCHP. EPA has slight confidence in the aspects of the exposure estimate for solid articles because of the high uncertainty in the assumption of partitioning from solid to liquid, and because subsequent dermal absorption is not well characterized. However, other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in an overall confidence of moderate in a health protective estimate.	Dermal – Moderate
Other; Other consumer articles that contain dicyclohexyl phthalate	Two different scenarios were assessed under this COU for articles with differing use patterns. The scenarios of outdoor seating (single article in use), and small articles with potential for routine contact (multiple articles) were evaluated. These two scenarios were assessed for dermal exposures. Dermal	Dermal – Moderate

Consumer COU Category and Subcategory	Weight of Scientific Evidence	Overall Confidence
from: inks, toner and colorants; paints and coatings; adhesives and sealants (*e.g.*, paper products, textiles, products using cellulose film, etc.)	absorption estimates assumed that dermal absorption of DCHP from solid objects would be limited by the aqueous solubility of DCHP. EPA has slight confidence in the aspects of the exposure estimate for solid articles because of the high uncertainty in the assumption of partitioning from solid to liquid, and because subsequent dermal absorption is not well characterized. However, other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in an overall confidence of moderate in a health protective estimate.	

5.2 Indoor Dust Monitoring Weight of Scientific Evidence

The weight of scientific evidence (WOSE) for the indoor dust exposure assessment of DCHP (Table 5-2**)** is dependent on studies that include indoor residential dust monitoring data (Table 4-1). Only studies that included indoor dust samples taken from residences were included for data extraction. In the case of DCHP, three studies were identified as containing data on indoor environments in the United States and were selected for use in the indoor dust monitoring assessment as described in Section 4.1, Rudel et al. (2001), Guo and Kannan (2011), and Dodson et al. (2015). The Rudel et al. (2001) and Guo and Kannan (2011) studies were rated "High" quality per the exposure systematic review criteria and Dodson et al. (2015) was rated "Medium" quality per the exposure systematic review criteria. The systematic review ratings for the studies are high and medium indicating good reporting and description of the monitoring from the authors. However, the use of these studies' data in this risk assessment to represent the U.S. population is a factor considered in the designation of overall confidence in Table 5-2. The low number of samples within each study, and few localities, are used to assign a slight confidence in the overall use of these data for risk estimates or representative of the U.S. population.

Table 5-2. Weight of Scientific Evidence Conclusions for Indoor Dust Ingestion Exposure

Scenario	Confidence in Data Used [a]	Confidence in Model Inputs		Weight of Scientific Evidence Conclusion
		Body Weight [b]	Dust Ingestion Rate [c]	
Indoor exposure to residential dust via ingestion	Slight	Robust	Moderate	Slight

[a] Rudel et al. (2001), Guo and Kannan (2011), Dodson et al. (2015)
[b] U.S. EPA (2011b)
[c] Özkaynak et al. (2022)

Table 5-2 presents the level of confidence in the data quality of the input data sets for estimating dust ingestion from monitoring data, including the DCHP dust monitoring data (Confidence in Data Used column in Table 5-2), 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 the assessor 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 the assessor is making the best scientific assessment possible in the 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 the assessor's professional judgment (see Table 5-2).

Monitoring data collected in the United States were identified for DCHP in Rudel et al. (2001), Guo and Kannan (2011), and Dodson et al. (2015). In Rudel et al. (2001), six indoor dust samples were collected from multiple surfaces in offices and various home environments (attic, living room, and basement). In Guo and Kannan (2011) 33 carpet flooring dust samples were collected in several homes between 2007 and 2008 in New York. Lastly in Dodson et al. (2015), 49 dust samples were collected from multiple surfaces in homes in California in 2006. Although the studies have differing numbers of samples, sampling surfaces, indoor environments, and locations, the low number of studies, sampling locations, and samples do not capture a representative indoor dust U.S. distribution. EPA assigned slight confidence to the use of these studies reporting dust concentrations.

Body weight data was obtained from the *Exposure Factors Handbook* (U.S. EPA, 2011b). This source is considered the default for exposure related inputs for EPA risk assessments and is typically used unless there is a particular reason to seek alternative data. Because the Handbook is generally considered the gold standard input for body weight, and because the underlying body weight data were derived from the U.S. nationally representative NHANES data set, EPA has assigned robust confidence to the use of this model input.

Total daily dust intake was obtained from Özkaynak et al. (2022). This study used a mechanistic modeling approach to aggregate data from a wide variety of input variables (Table 5-3). These input variables were derived from several scientific sources as well as from the professional judgment of the study authors. The dust ingestion rates are similar to those found in the *Exposure Factors Handbook* for children less than 1 year old but diverge above this age (U.S. EPA, 2011a) (Table 5-4). The Özkaynak et al. (2022) dust ingestion rates are one-half to approximately one-fifth as large, depending on age. This is because the Handbook rates are a synthesis of several studies in the scientific literature, including tracer studies that use elemental residues in the body to estimate the ingestion of soil and dust. According to the discussion presented in Özkaynak et al. (2022), these tracer studies may be biased high, and in fact as shown in Figure 4 of Özkaynak et al. (2022), non-tracer studies align much more closely with the dust ingestion rates used in this analysis. Because some input variables were unavailable in the literature and had to be based on professional judgment, and the dust ingestion rates differ from those in the Handbook, EPA has assigned moderate confidence to this model input.

5.2.1 Assumptions in Estimating Intakes from Indoor Dust Monitoring

5.2.1.1 Assumptions for Monitored DCHP Concentrations in Indoor Dust

The DCHP concentrations in indoor dust were derived from Rudel et al. (2001), Guo and Kannan (2011), and Dodson et al. (2015). The studies identified the sampling locations and rooms as typical indoor locations. A key assumption made in this analysis is that dust concentrations in living rooms, attics, basements, and offices are representative of those in the remainder of the home. Another important assumption is that a very small number of samples and localities within the studies' data is assumed to represent the U.S. population.

5.2.1.2 Assumptions for Body Weights

Body weights were taken from the *Exposure Factors Handbook* (U.S. EPA, 2011b), in which they were derived from the NHANES 1999 to 2006 data set. The NHANES studies were designed to obtain a nationally representative data set for the United States and include weight adjustment for oversampling of certain groups (children, adolescents 12 to 19 years, persons 60+ years of age, low-income persons, African Americans, and Mexican Americans). Body weights were aggregated into the age ranges shown in Table 4-2 and Table 4-3 and were averaged by sex.

5.2.1.3 Assumptions for Dust Ingestion Rates

To estimate daily intake of DCHP in residential indoor dust, a daily rate of dust ingestion is required. EPA used rates from Özkaynak et al. (2022) that modeled to estimate dust and soil intakes for children from birth to 21 years of age. A probabilistic approach was used in that study to assign exposure parameters including behavioral and biological variables. The exposure parameters are summarized in Table 5-3 and the statistical distributions chosen are reproduced in detail in the supplemental material for Özkaynak et al. (2022).

Table 5-3. Summary of Variables from Özkaynak et al. 2022 Dust/Soil Intake 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/hour	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 washed	1/day	Zartarian et al. (2005)
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)

Variable	Description	Units	Source
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

5.2.1 Uncertainties in Estimating Intakes from Monitoring Data

5.2.1.1 Uncertainties for Monitored DCHP Concentrations in Indoor Dust

Indoor dust concentrations were derived from Rudel et al. (2001), Guo and Kannan (2011), and Dodson et al. (2015), which sampled residential house dust in New York and California. Uncertainties arise from the low number of samples and localities within the monitoring studies used to represent the U.S. population. It is possible that sampling biases were introduced by the choice of study location, by the choice to include only households that contain children, and by differences among the households that chose to participate in the study. Differences in consumer behaviors, housing type and quality, tidiness, and other variables that affect DCHP concentrations in household dust are possible between participating households and the general population.

5.2.1.2 Uncertainties for Body Weights

Body weights were obtained from *Exposure Factors Handbook* (U.S. EPA, 2011b), 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 DCHP dose per unit body weight, because actual body weights in the U.S. population may be larger than those assumed in this analysis.

5.2.1.3 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 5-3). Each of these parameters is subject to uncertainty—especially those that 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 5-4).

Table 5-4. Comparison between Özkaynak et al. 2022 and *Exposure Factors Handbook* Dust Ingestion Rates

Age Range		0–<1 m	1–<3 m	3–<6 m	6 m–<1 y	1–<2 y	2–<3 y	3–<6 y	6–<11 y	11–<16 y	16–<21 y
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

m = month(s); y = year(s)
[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 two sources in this instance.

The Özkaynak et al. (2022) dust intake estimates for children above 1 year old are substantially lower than those in the *Exposure Factors Handbook* (U.S. EPA, 2011b), while the estimate 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 study, 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 Fig. 4, Özkaynak et al. (2022)).

5.2.1.4 Uncertainties in Interpretation of Monitored DCHP Dose Estimates

There are several potential challenges in interpreting available indoor dust monitoring data. The challenges include the following:

- Number of samples and locations used to represent the U.S. population.
- 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 DCHP that included non-TSCA COUs.
- None of the identified monitoring data contained source apportionment information that could be used to determine the fraction of DCHP in dust samples that resulted from a particular TSCA or non-TSCA COU. Therefore, these monitoring data represent background concentrations of DCHP 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 TOWARDS RISK CHARACTERIZATION

Indoor Dust

For the indoor exposure assessment, EPA considered modeling and monitoring data. Monitoring data is expected to represent aggregate exposure to DCHP 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 exposure through dust. However, available DCHP monitoring data had few samples and study locations. Without additional samples it is difficult to determine if the data is representative of the U.S. population. There were no indoor modeling article or product scenarios that could be used to assess indoor DCHP releases and potential exposures.

Due to the slight confidence evaluation of the monitoring assessment, a risk estimate based on these data was not derived. Additionally, because the monitoring data was not found to be representative of the U.S. population and was not apportioned to DCHP-containing items, the typical monitoring and modeling dose comparison was unlikely to yield useful information.

Consumer

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

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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.

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 DCHP in air (mg/m^3)
Inh	=	Inhalation rate (m^3/hr)
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/hr)

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 and so on:

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

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

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)
	$DCHPRP_{air\_max}$	=	Maximum DCHP 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/hr)
	CF_1	=	Conversion factor (24 hr/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)
	$DCHPRP_{air\_max}$	=	Maximum DCHP in respirable particles (RP) concentration, air (µg/mg)
	RP_{air_max}	=	Maximum RP concentration, air (mg/m^3)
	IF_{TSP}	=	RP ingestion fraction (unitless)
	$DCHPDust_{air\_max}$	=	Maximum DCHP in dust concentration, air (µg/mg)
	$Dust_{air\_max}$	=	Maximum dust concentration, air (mg/m^3)
	IF_{Dust}	=	Dust ingestion fraction (unitless)
	$DCHPAbr_{air\_avg}$	=	Maximum DCHP 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/hr)
	CF_1	=	Conversion factor (24 hr/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/hr)
	CA	=	Contact area of mouthing (cm^2)
	D_m	=	Duration of mouthing (min/hr)
	ED_{ac}	=	Exposure duration, acute (days)
	CF_1	=	Conversion factor (24 hr/day)
	BW	=	Body weight (kg)
	AT_{ac}	=	Averaging time, acute (days)

CF_2 = Conversion factor (60 min/hr)

See Section 2.2.3.1 for migration rate inputs and determination of these values.

Acute dose rate for incidental ingestion of dust (CEM A_ING3 model) was calculated as follows:

The article model named E6 in CEM calculates DCHP concentration in small particles, termed respirable particles (RP), and large particles, termed dust, that are settled on the floor or surfaces. The model assumes the particles bound to DCHP 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 DCHP-containing dust. The model uses a weighted dust concentration, shown below.

Equation_Apx A-7. Acute Dust Concentration

$$Dust_{ac\_wgt} = \frac{(RP_{floor\_max} \times DCHPRP_{floor\_max}) + (Dust_{floor\_max} \times DCHPDust_{floor\_max}) + (AbArt_{floor\_max} \times DCHPAbArt_{floor\_max})}{(TSP_{floor\_max} + Dust_{floor\_max} + AbArt_{floor\_max})}$$

Where:

$Dust_{ac\_wgt}$ = Acute weighted dust concentration (µg/mg)
RP_{floor_max} = Maximum RP mass, floor (mg)
$DCHPRP_{floor\_max}$ = Maximum DCHP in RP concentration, floor (µg/mg)
$Dust_{floor\_max}$ = Maximum dust mass, floor (mg)
$DCHPDust_{floor\_max}$ = Maximum DCHP in dust concentration, floor (µg/mg)
$AbArt_{floor\_max}$ = Maximum abraded particles mass, floor (mg)
$DCHPAbArt_{floor\_max}$ = Maximum floor dust DCHP 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 DCHP can volatilize from the DCHP-containing article to the air and then partition to dust. Alternately, DCHP can partition directly from the article to dust in direct contact with the article. This is also estimated in A_ING3 model assuming the original DCHP 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 DCHP in Dust

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

Where:

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

Once DCHP 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 DCHP 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 module) 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/hr)
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/hr)

CEM uses two defaults inhalation rates which trace to the Exposure Factors Handbook (see Table_Apx A-1 footnote), 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	Inhalation Rate During Use (m^3/hr)[a]	Inhalation Rate After Use (m^3/hr)[b]
Adult (≥ 21 years)	0.74	0.61
Youth (16–20 years)	0.72	0.68
Youth (11–15 years)	0.78	0.63
Child (6–10 years)	0.66	0.5
Small Child (3–5 years)	0.66	0.42
Infant (1–2 years)	0.72	0.35
Infant (<1 year)	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

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

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)
$DCHPRP_{air\_avg}$	=	Average DCHP 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/hr)
CF_1	=	Conversion factor (24 hr/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 follows:

The CEM article model, E6, estimates DCHP concentrations in small and large airborne particles. While 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 DCHP bound to airborne small particles, respirable 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

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

Where:

$CADD_{IAI}$	=	Chronic Average Daily Dose from ingestion after inhalation (mg/kg-day)
$SVOCRP_{air\_avg}$	=	Average DCHP in RP concentration, air (µg/mg)
RP_{air_avg}	=	Average RP concentration, air (mg/m^3)
IF_{RP}	=	RP ingestion fraction (unitless)
$SVOCDust_{air\_avg}$	=	Average DCHP dust concentration, air (µg/mg)
$Dust_{air\_avg}$	=	Average dust concentration, air (mg/m^3)
IF_{Dust}	=	Dust ingestion fraction (unitless)
$SVOCAbr_{air\_avg}$	=	Average DCHP 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/hr)
CF_1 = Conversion factor (24 hr/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 follows:

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 for migration rate inputs and determination of these values.

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

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

Where:

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

Chronic average daily rate for incidental ingestion of dust (CEM A_ING3 model) was calculated as follows:

The article model in CEM E6 calculates DCHP concentration in small particles, termed respirable particles (RP), and large particles, termed dust, that are settled on the floor or surfaces. The model assumes these particles, bound to DCHP, 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 DCHP-containing dust. The model uses a weighted dust concentration, shown below.

Equation_Apx A-18. Chronic Dust Concentration

$$Dust_{cr\_wgt} = \frac{\left(RP_{floor\_avg} \times DCHPRP_{floor\_avg}\right) + \left(Dust_{floor\_avg} \times DCHPDust_{floor\_avg}\right) + \left(AbArt_{floor\_avg} \times DCHPAbArt_{floor\_avg}\right)}{\left(RP_{floor\_avg} + Dust_{floor\_avg} + AbArt_{floor\_avg}\right)}$$

Where:

$Dust_{cr\_wgt}$ = Chronic weighted dust concentration (µg/mg)
RP_{floor_avg} = Average RP mass, floor (mg)
$DCHPRP_{floor\_avg}$ = Average DCHP in RP concentration, floor (µg/mg)
$Dust_{floor\_avg}$ = Average dust mass, floor (mg)

$DCHPDust_{floor\_avg}$ = Average DCHP in dust concentration, floor (µg/mg)
$AbArt_{floor\_avg}$ = Average abraded particles mass, floor (mg)
$DCHPAbArt_{floor\_avg}$ = Average floor dust DCHP 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 DCHP can volatilize from the DCHP-containing article to the air and then partition to dust. Alternately, DCHP 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 DCHP 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. The 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 2-8 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:

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[a]	Events Per Month[a]
Construction Adhesive for Small Scale Projects	3	4
Construction Sealant for Large Scale Projects	1	3
Lacquer Sealer (Non-Spray)	1	2
Lacquer Sealer (Spray)	1	2
[a] Events per day and month values determined using professional judgement based on manufacturer product description use.		

A.4 Dermal Absorption Dose Modeling for Acute and Chronic Exposures

After calculating dermal absorption dose per event for each lifestage, chronic average daily dose, acute average daily dose, and intermediate average daily dose were calculated as described below.

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

Equation_Apx A-21. Acute Dose Rate for Dermal

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

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
$Acute\ Frequency$	=	Number of exposure events per averaging period
$Averaging\ Time$	=	Acute averaging time, day $^{-1}$

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

Equation_Apx A-22. Chronic Average Daily Dose Rate for Dermal

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

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, and
$Chronic\ Frequency$	=	Number of exposure events per averaging period
$Averaging\ Time$	=	Chronic averaging time, day $^{-1}$