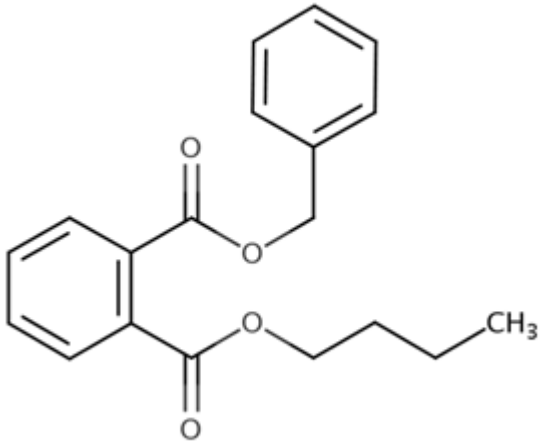
United States
Environmental Protection Agency

EPA Document# EPA-740-R-25-020
December 2025
Office of Chemical Safety and
Pollution Prevention

Consumer and Indoor Exposure Assessment for Butyl Benzyl Phthalate (BBP)

Technical Support Document for the Risk Evaluation

CASRN 85-68-7



December 2025

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

KEY ABBREVIATIONS AND ACRONYMS

ADR	Average dose rate
ADME	Absorption, distribution, metabolism, and excretion
BBP	Butyl benzyl phthalate, di-(2-ethylhexyl) phthalate
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 (U.S.)
CPSIA	Consumer Product Safety Improvement Act
COU	Condition of use
DBP	Dibutyl phthalate
DIY	Do-it-yourself
EPA	Environmental Protection Agency (U.S.)
HPCDS	High Priority Chemicals Data System
MCCEM	Multi-Chamber Concentration and Exposure Model
MSDS	Material safety data sheet
NHANES	National Health and Nutrition Examination Survey (CDC)
OCSPP	Office of Chemical Safety and Pollution Prevention (EPA)
OPPT	Office of Pollution Prevention and Toxics (EPA)
POD	Point of departure
PU	Polyurethane
PVC	Polyvinyl chloride

SDS	Safety data sheet
SVOC	Semi-volatile organic compound
TSCA	Toxic Substances Control Act
TSD	Technical support document
U.S.	United States
w/w	Weight per weight

SUMMARY

BBP – Consumer Exposure Assessment Summary:
Key Points

EPA (or the Agency) evaluated human exposure to butyl benzyl phthalate (BBP) in consumer products resulting from conditions of use (COUs) as defined under the Toxic Substances Control Act (TSCA). These include solid articles such as air beds, car mats, clothing, footwear, furniture components and textiles, vinyl flooring and carpeting tiles, wallpaper, shower curtains, and children's toys; liquid products including adhesives, sealants, and paints; and coated textile products used in clothing.

Exposure Approaches and Methodology Key Points (Section 2)

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

Exposure Dose Results Key Points (Section 3)

- The highest chronic exposure estimated for all life stages from infant (bystander) to adult (user) was for inhalation exposure to crafting resins for infants. Dermal exposure doses are generally higher than inhalation for all chronic scenarios except inhalation exposures from crafting resins and vinyl flooring.
- The highest acute exposure estimated for all life stages from infant to adult was for dermal exposure to crafting resins for toddlers.
- Inhalation of BBP-contaminated dust is an important contributor to indoor exposures. Most of the products and articles do not have a mouthing estimate, but ingestion doses of settled dust remain comparable to those from mouthing, suggesting settled dust ingestion is an important contributor to BBP exposures.

This technical support document (TSD) accompanies the TSCA *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2025d) and provides detailed descriptions of BBP consumer and indoor exposure assessments. BBP is a phthalate ester (CASRN 85-68-7) with several chemical names, including benzyl butyl benzene-1,2-dicarboxylate, benzyl butyl phthalate, and 1,2-benzenedicarboxylic acid. BBP is primarily used as a plasticizer in polyvinyl chloride (PVC) in consumer, commercial, and industrial applications, though it is also used in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as for other applications. It is added to certain products because its large molecular size and strongly hydrophobic chemical structure result in waterproof qualities in the finished good. As such, products containing BBP tend to be specialized in their intended use. BBP is also added to support flexibility in products such as car mats and other plastics. This assessment considers human exposure to BBP in consumer products resulting COUs as defined under TSCA. The major routes of exposure considered were ingestion via mouthing, ingestion of suspended dust, ingestion of settled dust, inhalation, and dermal exposure. The exposure durations considered were acute, intermediate, and

chronic. Acute exposures are for an exposure duration of 1 day, chronic exposures are for an exposure duration of 1 year, and intermediate exposures are for an exposure duration of 30 days.

For inhalation and ingestion exposures, EPA used CEM to estimate acute and chronic exposures to consumer users and bystanders. Intermediate exposures were calculated from the CEM daily exposure outputs for applicable scenarios (U.S. EPA, 2025b) outside of CEM because the exposure duration for intermediate scenarios is outside the 60-day modeling period CEM uses. For each scenario, high-, medium-, and low-intensity use exposure scenarios were developed in which values for duration of use, frequency of use, and surface area were determined based on reasonably available information and professional judgment (see Section 2.2 for CEM parameterization and input selection). Overall confidence in the estimates were robust or moderate depending on product or article scenario (Section 5.1). In brief, CEM default scenarios were selected for mass of product used, duration of use, and frequency of use. Generally, when using CEM defaults EPA has robust confidence. When no CEM default was available or applicable for some products, manufacturer instructions and online retailers provided details on recommended use of the product (*e.g.*, mass of product used during product application) (see Section 2.2.3.2). Most inhalation and ingestion product use patterns overall confidence were robust because the supporting evidence provided product specific information.

For articles, key parameters that control BBP emission rates from articles in CEM models are weight fraction of BBP in the material, density of article material, article surface area, and surface layer thickness. For articles that do not have default CEM inputs, EPA's *Exposure Factors Handbook* (also called "the Handbook") (U.S. EPA, 2011c) or professional judgment was used to select the duration of use and article surface area for the low-, medium-, and high-exposure scenario levels for most articles. Most inhalation and ingestion article use patterns overall confidence was rated robust because the source of the information was either the Handbook, or when using professional judgment, EPA based selection of inputs on online article descriptions for article surface area (see Section 2.2.3.1). The Agency has moderate confidence in ingestion via mouthing estimates due to uncertainties about professional judgment inputs regarding mouthing durations for adult toys and synthetic leather furniture for children. In addition, the chemical migration rate input parameter has a moderate confidence due to the large variability in the empirical data used in this assessment and unknown correlation between chemical migration rate and BBP concentration in articles. See Section 5.1 for a detailed discussion of confidence in exposure doses and sources of uncertainty in the approaches, modeling, and inputs.

Dermal exposures for both liquid products and solid articles were calculated outside of CEM, see *Consumer Exposure Analysis for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2025a) for calculations and inputs. CEM dermal modeling uses a dermal model approach that assumes infinite BBP migration from product to skin without considering saturation, which result in overestimations of dose and subsequent risk, see Section 2.3 for a detailed explanation. Low-, medium-, and high-intensity use exposure scenarios were developed for each product and article scenario by varying values for duration of dermal contact and area of exposed skin. Confidence in the dermal exposure estimates were moderate depending on uncertainties associated with input parameters. The flux-limited screening dermal absorption approaches for liquid and solid products and articles assumes a constant rate of absorption of BBP in contact with the skin independent of BBP concentration in the article/product. The flux-limited screening approach provides an upper bound of dermal absorption of BBP and results in some overestimations (see Section 5.1 for a detailed discussion on limitations, strengths, and confidence in dermal estimates). In brief, inputs for duration of dermal contact were either from the Handbook (U.S. EPA, 2011c) or professional judgment based on product and article manufacturer use descriptions. For products, manufacturer instructions provide details on recommended use of the product (*e.g.*, adhesives and sealants). However, for articles, typically such data are not available from manufactures. Sometimes

inputs can be found in the Handbook (*e.g.*, vinyl flooring contact duration), other times professional judgment is used; for example, length of time an individual spends sitting on a couch per day for medium- and low-intensity use scenarios).

The highest chronic exposure estimated for all life stages from infant (bystander) to adult (user) was for inhalation exposure to crafting resins for infants. The inhalation exposure from crafting resins for infant is a bystander scenario, in which infants are not users of the product but are exposed from proximity use of the product by a user. Dermal exposure doses are generally higher than inhalation for all chronic scenarios except inhalation exposures from crafting resins and vinyl flooring. Chronic inhalation exposure doses of suspended dust from children's toys are higher than chronic ingestion doses of children's toys by almost an order of magnitude. Under the Consumer Product Safety Improvement Act (CPSIA) of 2008, Congress permanently prohibited the sale of children's toys or childcare articles containing concentrations of more than 0.1 percent BBP (CPSIA section 108(a); 15 U.S.C. § 2057c(a); and 16 CFR 1307.3(a)). However, it is possible that some individuals may still have children's toys in the home that were produced before regulatory and statutory limitations. Dermal doses are generally higher than inhalation for all acute scenarios, except vinyl flooring. The highest acute exposure estimated for all life stages from infant to adult was for dermal exposure to crafting resins for toddlers. Inhalation of BBP-contaminated dust is an important contributor to indoor exposures. Most of the products and articles do not have a mouthing estimate, but ingestion doses of settled dust remain comparable to those from mouthing, suggesting settled dust ingestion is an important contributor to BBP exposures.

1 INTRODUCTION

BBP is a phthalate ester (CASRN 85-68-7) with properties used to support product flexibility and hydrophobicity. BBP is primarily used as a plasticizer in polyvinyl chloride (PVC) in consumer, commercial, and industrial applications, though it is also used in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as for other applications. These include PVC used in solid articles such as car mats, clothing, furniture components and textiles, vinyl flooring, tire crumb, and children's toys; and liquid products including adhesives, sealants, automotive lubricants, crafting resins, inks and dyes, and paints. The CPSIA of 2008 permanently prohibited the sale of children's toys or childcare articles containing concentrations exceeding 0.1 percent BBP (CPSIA section 108(a)). However, it is possible that some homes still have children's toys in the home that were produced before regulatory and statutory limitations. EPA 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, to identify products and articles under the defined COUs of BBP for inclusion in the risk evaluation (Table 1-1). Consumer products and articles were identified and matched to COUs. Weight fractions of BBP in specific items were then gathered from a variety of sources, such as safety data sheets (SDS), databases, and literature-reviewed publications. These data were used in this assessment in a tiered approach, as described in Section 2.1.

The migration of BBP 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 BBP has not been well characterized. The identified uses can result in exposures to consumers and bystanders (*i.e.*, non-product users that are incidentally exposed to the product). For all the BBP-containing consumer products identified, the approach involves addressing the inherent uncertainties by modeling high-, medium-, and low-exposure scenarios. Due to the lack of comprehensive data on various parameters and the expected variability in exposure pathways, EPA used conservative screening approaches to obtain exposure doses associated with BBP across COUs and various age groups.

Because PVC products are ubiquitous in modern indoor environments, and since BBP is not chemically bound to many consumer products and articles in which it is incorporated, it can migrate to particulate or evaporate (to a lesser extent based on physical and chemical properties) into indoor air and concentrate in household dust. Dust has a complex combination of organic and inorganic matter and as such, BBP has a high affinity to organic matter, which is expected to promote migration from products and articles to 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, and place their hands and objects in their mouths. EPA estimated exposures were assessed and compared for children of various ages and adults.

Table 1-1. Consumer Conditions of Use Table

Life Cycle Stage	Category	Subcategory of Use	Reference(s)
Consumer	Construction, paint, electrical, and metal products	Paints and coatings	(Ford Motor Company, 2019; Multi-Tech Products Corp, 2015)
		Adhesives and sealants	(U.S. EPA, 2020, 2019a)
	Furnishing, cleaning, treatment/care products	Fabric, textile, and leather products	(NLM, 2015)
		Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles; fabrics, textiles, and apparel	(U.S. EPA, 2020, 2019a)
	Packaging, paper, plastic, hobby products	Arts, crafts, and hobby materials	(BJB Enterprises, 2022, 2021)
		Toys, playground, and sporting equipment	(U.S. EPA, 2024b, c, 2019b, c; CPSC, 2015)
		Ink, toner, and colorant products	(NLM, 2015)
		Packaging (excluding food packaging) and other articles with routine direct contact during normal use, rubber articles; plastic articles (hard); plastic articles (soft)	(NLM, 2015)
	Other uses	Automotive products, fluids	(Permatex, 2020; MEMA, 2019; Armored AutoGroup Inc., 2015)
		Automotive articles	(ACC, 2019; MEMA, 2019; U.S. EPA, 2019c; NLM, 2015)
		Novelty articles	(Sipe et al., 2023)

2 CONSUMER EXPOSURE APPROACH AND METHODOLOGY

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

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 or articles containing BBP 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 modeled, an indication of scenarios used in the indoor dust assessment, and whether the analysis was done qualitatively or quantitatively. The indoor dust assessment uses consumer products 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. The qualitative analysis is a discussion of exposure potential based on physical and chemical properties, and/or available monitoring data, if available. When a quantitative analysis was conducted, exposure from the consumer COUs was estimated by modeling. Each product or article was individually assessed to determine whether all or some exposure routes were applicable, and approaches were developed accordingly.

Exposure via inhalation and ingestion routes were modeled using EPA's CEM Version 3.2 (U.S. EPA, 2023). Dermal exposure to BBP-containing consumer products was estimated using a computational framework implemented within a spreadsheet. Refer to Dermal Modeling Approach in Section 2.2 for a detailed description of dermal approaches, rationale for analyses conducted outside CEM, as well as 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 the COU. 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 *Risk Evaluation for Butyl Phthalate (BBP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025a). High-, medium-, and low-intensity use exposure scenarios serve as a two-pronged approach. First, it provides a sensitivity analysis with insight on the impact of the main modeling input parameters (*e.g.*, skin contact area, duration of contact, and frequency of contact) in the doses and risk estimates. And second, the high-intensity use exposure scenarios are used first to screen for potential risks at the upper bound of possible exposures, and to refine if needed. Throughout this assessment/TSD, the consumer-related spreadsheets, as well as the risk

evaluation, the reporting order is high-, medium-, and low-intensity use exposure scenarios.

Based on reasonably available information from the systematic review process on consumer COUs and indoor dust studies, inhalation of BBP is possible through BBP emitted from products and articles and BBP sorbed to indoor dust and particulate matter. A detailed discussion of indoor dust references, sources, and concentrations is available in Section 4. Due to BBP's low volatility there is expected to be negligible or very small gas-phase inhalation exposures. However, BBP's physical and chemical properties, such as low vapor pressure, low solubility, and high octanol-air partition coefficient (K_{OA}) suggest a high affinity for organic matter that 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 BBP in settled dust from indoor environments. Due to the presence of BBP in indoor dust, inhalation and ingestion of suspended dust and ingestion of settled dust are both considered as exposure routes in this consumer assessment.

Based on reasonably available information from the systematic review of consumer COUs and indoor dust studies, oral exposure to BBP 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 COUs identified for BBP, oral and dermal exposures to consumers were assessed.

Qualitative analyses describing low exposure potential are 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 BBP, emissions to air from solid articles are expected to be relatively low. As such, articles with a small surface area (less than ≈1 m^2) and articles used outdoors were not assessed for inhalation exposure. For items with small surface area for emissions and dust collection, the potential for emission to air and dust is further reduced. To verify this assumption, a CEM test run for a generic 1 m^3 item with 30 percent BBP content by weight was carried out. The combined doses from inhalation and dust ingestion were 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 *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2025d). Similarly, solid articles are not expected to be mouthed for a significant period of time (*e.g.*, building materials, sports equipment.) and were therefore not assessed for that route of exposure.

EPA assessed acute, chronic, and intermediate, and lifetime exposures to BBP from consumer COUs. For the acute dose rate calculations, an averaging time of 1 day is used, representing the maximum time-integrated dose over a 24-hour period in which the exposure event occurs. The chronic dose rate is calculated iteratively at a 30-second interval during the first 24 hours, every hour after that for 60 days, and averaged over 1 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 BBP Content

Products with BBP content are generally consumable liquids, aerosols, or semi-solids that are used a given number of times before they are exhausted. Articles with BBP content 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 BBP content in U.S.

consumer goods were safety data sheets (SDSs) for specific products or articles with reported BBP content, peer-reviewed literature providing measurements of BBP in consumer goods purchased in the United States, and U.S. government reports originating in with manufacturer-reported concentrations. In instances where these data from preferred sources were not available, BBP content in specific products and articles provided in peer reviewed literature and government reports originating from Canada and the European Union were used. Manufacturing practices and regulations for BBP in consumer goods are comparable between these regions and the United States, so it is reasonable to assume that similarly formulated products may be available across these regions. BBP weight fractions reported in the CDR database were not used as reported values may pertain to a finished good in the product category reported, or it could represent a chemical additive that will be added to other components during the manufacturing process of the finished good.

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

In addition to BBP 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 section provides a summary of specific products and articles with BBP 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

Although BBP is known to be used in a large variety of solid articles, weight fraction data for solid articles containing BBP and currently sold in the United States was 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 BBP weight fraction data used in this assessment from the HPCDS database corresponds to the 2017 to 2024 reporting period. Concentration ranges (*e.g.*, 100–10,000 ppm) based on test results or manufacturer knowledge are provided. Additionally, for specific products or articles that were not identified, EPA used generic categories. However, HPCDS does not identify specific products or articles, only generic categories (*e.g.*, toys/games) are provided.

As data for BBP content in solid items not specific to children were lacking for U.S. consumer goods, data was obtained from monitoring campaigns of phthalates in consumer goods performed in European countries. Some data were available for phthalates in consumer goods published across several studies conducted by the Danish EPA (Danish EPA, 2020). For articles that did not have U.S. data, EPA assessed these items under the assumption that the weight fractions reported by the Danish EPA are representative of BBP content that may be present in items sold in the United States.

Given the high molecular weight (312.37 g/mol) and low vapor pressure (8.25×10^{-6} mmHg) of BBP, 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 below for articles with potential for semi-routine dermal exposure).

For articles assessed for mouthing and/or dermal contact the weight fraction data are used to confirm the presence of BBP in the article, but these data are not used in the dermal modeling, see Section 1.1. Furthermore, dermal, and mouthing exposure 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).

Adult Toys

Adult toys, also known as intimacy and sex toys, are objects that people use to increase or facilitate sexual pleasure. Examples of adult toys include vibrators and dildos. These articles were assessed for BBP exposure by mouthing and dermal routes. Vaginal and anal exposures, labeled as adult toy mucosal membrane exposures, were not quantitatively assessed due to a lack of use pattern information and modeling tools to calculate exposure for articles with vaginal and anal use. BBP was reported at 2.6×10^{-5} weight per weight (w/w) in an adult toy sample purchased in the U.S. (Sipe et al., 2023).

Car Mats

Car floor mats were assessed for BBP exposure by inhalation, dust ingestion, and dermal exposure routes. Dermal contact occurs primarily during cleaning. The only available data for BBP content in car mats was one car mat set purchased from an internet vendor in Denmark, with reported BBP weight fraction of 5×10^{-5} w/w (Danish EPA, 2020). As data specific to the U.S. market is lacking, this value was used in low-, medium-, and high-exposure scenarios.

Children's Toys

Children's toys were assessed for BBP exposure by inhalation, dust ingestion, dermal and mouthing routes of exposure. Under the CPSIA of 2008, Congress permanently prohibited the sale of children's toys or childcare articles containing concentrations of more than 0.1 percent BBP (CPSIA section 108(a); 15 U.S.C. § 2057c(a); and 16 CFR 1307.3(a)). However, it is possible that some individuals may still have children's toys in the home that were produced before regulatory and statutory limitations.

In the U.S. market, among the data for children's items from the Washington State database, there were no toy items with detectable concentrations of BBP (WSDE, 2020). The HPCD database contained data for BBP measurements in 55 toy/game items. BBP content was reported to be less than 100 ppm (<0.0001 w/w) in 25 items, 100 to 500 ppm (0.0001–0.0005 w/w) in 22 items, 500 to 1,000 ppm (0.0005–0.001 w/w) in 6 items, and 1,000 to 5,000 ppm (0.001–0.005 w/w) in two items (WSDE, 2020). No identifying details were found about the two items with BBP content above the regulatory limit of 0.1 percent under CPSIA. Toy items were generally described as dolls, doll furniture, action figures, puppets, board games, card games, developmental toys, scientific toys, and soft toys.

As such, EPA assessed exposure to BBP in children's toys under two scenarios. In the first, new toys produced for the U.S. market are assumed to comply with the regulatory limit (0.1%) and were therefore assessed with BBP weight fraction of 0.001 w/w in low-, medium-, and high-exposure scenarios as a conservative assumption. In the second exposure scenario, legacy toys are assessed with weight fractions reported in the HPCDS database (WSDE, 2020) that were above the regulatory limit of 0.001

w/w. Based on the reported data, the weight fractions of BBP used in low-, medium-, and high-exposure scenarios were 0.001, 0.003, and 0.005 w/w, respectively. Two new toys in the Washington State database tested 12 or more years after the CPSIA had components with BBP content above the regulatory limit of 0.01 percent (WSDE, 2020). The legacy toys scenario is more representative of any new toys with weight fractions above the CPSIA regulatory limit.

Clothing

Clothing was assessed for BBP exposure by dermal contact only, but a different approach was taken for adults and children based on anticipated contact with specific garments and/or garment components containing BBP.

BBP has been reported in synthetic leather materials sampled from furniture items (see coated textiles description below). It is reasonable to assume that these materials may be used in synthetic leather clothing as well. As such, synthetic leather clothing was chosen as the representative clothing item for modeling dermal exposure to BBP in adults and teens.

For children, in the Washington State database, there was one clothing item (pajama top) where BBP was tentatively identified at 1.3×10^{-5} w/w in the exterior print (WSDE, 2020). The HPCD database contained data for BBP measurements in six children's clothing items including headwear and badges/buckles. BBP content was reported to be <100 ppm (<0.0001 w/w) in three items and 500 to 1,000 ppm (0.0005 to 0.001 w/w) in three items (WSDE, 2020). Given the very low concentration of BBP and limited dermal contact of these specific product types, BBP exposure from the reported items or similar items is not expected to be significant. As such, dermal exposure to BBP from clothing was not modeled explicitly for infants and children; however, the potential for dermal contact with these items is captured under the scenario "Solid articles with potential for semi-routine dermal exposure" outlined below.

Coated Textiles

Coated textiles were assessed for BBP exposure via inhalation, ingestion, and dermal uptake. The Danish EPA reported BBP content of 6.5×10^{-4} and 1.2×10^{-4} w/w in two synthetic leather furniture samples (Danish EPA, 2010b). Synthetic leather is expected to have many potential applications, including furniture, clothing, vehicle upholstery, and accessory items such as belts and handbags. Exposure to coated textiles was assessed as two representative articles expected to capture the highest exposure by inhalation, dermal uptake, and ingestion due to large surface area of emissions and long dermal contact times. To that end, consumer exposure to BBP from coated textiles was modeled in scenarios for synthetic leather furniture and clothing. The low-, medium-, and high-exposure scenarios for BBP in both scenarios used the minimum, average, and maximum reported weight fractions of 1.2×10^{-4}, 3.9×10^{-4}, and 6.5×10^{-4} w/w.

Flooring Materials

Vinyl flooring was assessed for BBP exposure by inhalation, dust ingestion, and dermal exposure routes. In a Danish EPA study, BBP was found in one vinyl covering at weight fraction of 0.0001 w/w. (Danish EPA, 2010b). In an ECHA proposal for restriction report, BBP was reported in three vinyl flooring materials at 0.0064 w/w, 0.0089 w/w, and 0.0044 w/w (Danish EPA, 2011). As data specific to the U.S. market is lacking, based on the data reported in these studies, the weight fraction values used in low-, medium-, and high-exposure scenarios for vinyl flooring were the minimum, average and maximum values of 0.0001 w/w, 0.005 w/w, and 0.009 w/w.

Tire Crumb

The exposure characterization provides concentrations of semi-volatile organic compounds (SVOCs) in air samples obtained from both outdoor (number of samples equal to 25) and indoor playing fields (n = 15) and a separate document published in conjunction provided measurements of BBP content in tire particles retrieved from the same locations (U.S. EPA, 2019c). Concentrations of BBP in air were not reported in the exposure characterization report. However, BBP concentrations in the tire particles themselves were reported in the associated tire particle characterization document and were similar to the reported content of DBP. Physical and chemical properties expected to significantly impact chemical transport including molecular weight, octanol air partitioning coefficient (K_{OA}), and solubility in water are similar between BBP and DBP; thus, it is reasonable to assume that air concentrations of DBP may provide a reasonable proxy for BBP. These data were used to develop estimates for exposure to BBP during sporting events on tire crumb fields as described below in Section 2.4.

Articles with Potential for Semi-Routine Dermal Exposure

BBP has been measured in a variety of consumer goods, which are not expected to be mouthed, are not expected to result in significant inhalation exposure due to their small size and are not expected to result in significant dermal exposures due to short and/or irregular dermal contact events. However, EPA recognizes that while dermal uptake of BBP from contact with these individual items is not expected to be significant, an individual could potentially have daily contact with some combination of these items and/or with other similar items that have not been measured during monitoring campaigns. As such, these items have been grouped together for modeling but represent a variety of TSCA COUs. It is likely that real-world exposures to these types of items would occur as a result of dermal contact with articles belonging to multiple COUs. However, the contribution of individual COUs to exposure from these kinds of items is expected to vary at an individual level due to differences in lifestyle and habits. As such, though this scenario encompasses items from more than one COU, it may be viewed as an upper boundary for exposure to any of the COUs included.

Weight fractions of BBP are not used in dermal exposure calculations, they are provided here only to demonstrate the variety of product types, formulations, and BBP contents that may be captured in this model scenario. BBP has been measured in various small plastic items reported in the Washington State database, including at 3.7×10^{-5} w/w in a vinyl liner, 1.3×10^{-5} w/w in the bottom surface of sandals, 9.2×10^{-6} to 9.8×10^{-4} w/w in plastic packaging, and 1.2×10^{-5} to 1.4×10^{-4} w/w in small plastic bags (*e.g.*, makeup and nail polish bags) (WSDE, 2020). In a study in Switzerland, BBP was measured in gloves from 0.02 to 0.03 w/w (Wormuth et al., 2006). A 2003 report submitted to CPCS, BBP was measured in two polymer modeling clay samples at 0.0017 w/w and 0.04 w/w (Stopford et al., 2003). In a 2002 report conducted by the VPIRG nonprofit group, BBP was measured at 0.015 w/w in Sculpey brand polymer clay products and 0.002 w/w in Fimo brand polymer clay products purchased from local stores in Vermont (VPIRG, 2002).

2.1.2 Liquid and Paste Products

Liquid and paste products with BBP content were identified by manufacturer safety data sheets (MSDSs). Products with similar BBP content and expected use patterns were grouped together for modeling as described below. As previously discussed, partitioning of BBP to air is limited by its large molecular weight and low volatility. As such, some products were not assessed for inhalation exposure because this route was not expected to be significant due to small volumes of product expected to be used, small windows of time for emissions to air (*e.g.*, adhesives with short working times until solidification and liquids poured directly into a reservoir that is capped after product addition), and products used in outdoor conditions where air exchange rates are high and product application is not expected to generate significant aerosols. For liquid and paste products assessed only for dermal

exposure, BBP content is provided here for context only as it is not used directly in exposure calculations for these routes (see Section 2.3 for details).

Adhesives for Small Repairs

Two adhesives were identified with BBP content, including a model and hobby cement with reported BBP content of 3.85 percent (Elmers, 2009) and a structural adhesive with reported BBP content of 10 to 20 percent (Royal Adhesives & Sealants, 2017). Based on these data the weight fractions of BBP used in low-, medium-, and high-exposure scenarios were 0.039, 0.09, and 0.2 w/w. Use of these products is not expected to result in significant inhalation exposure as very small quantities are used and working times are very short (<5 min). However, they were assessed for dermal exposure under the assumption that consumers may not immediately wash the product off after contact, resulting in dermal exposure durations longer than product working times. The weight fraction values are used to confirm BBP in the product and identify a possible weight fraction range to provide context about distribution and variability.

Automotive Lubricants

Two automotive lubricants were identified with BBP content, including a steering fluid with reported BBP content of 0 to 3 percent (Walmart, 2019) and a disc brake fluid with reported BBP content of 5 to 10 percent (Permatex, 2020). Based on these data the weight fractions of BBP used in low-, medium-, and high-exposure scenarios were 0.03, 0.05, and 0.1 w/w. Inhalation exposure is not expected to be significant for these products as they are not used in a way that allows for long periods of product-air contact (*e.g.*, product is poured directly into a reservoir then capped) and use is infrequent. However, they were assessed for dermal exposure under the assumption that consumers may not immediately wash the product off after contact, resulting in dermal exposure durations longer than product application times. The weight fraction values are used to confirm BBP in the product and identify a possible weight fraction range to provide context about distribution and variability.

Caulk/Sealants

Five products were identified for various outdoor repair and sealing applications, including for concrete, mortar, blacktop, stucco, and roofing. The reported BBP content was 4 to 10 percent in the blacktop sealant (DeLima Associates, 2018b), 1 to 2 percent in the concrete, mortal, and stucco sealants (DeLima Associates, 2018a; Quikrete, 2015a, b) and 10 to 30 percent in the roofing sealant (DAP Products, 2024). Based on these data the weight fractions of BBP used in low-, medium-, and high-exposure scenarios were the minimum, average and maximum values of 0.01, 0.06, and 0.3 w/w, respectively. As the anticipated use for these products was outdoors, and the products are not applied in a manner likely to generate aerosols, inhalation exposure is expected to be negligeable, and the products were modeled for dermal exposure only. Weight fraction values are used to confirm BBP in the product and identify a possible weight fraction range to provide context about distribution and variability.

Five products were identified for various indoor or outdoor repair and sealing applications, including for perimeter caulking (doors, windows), expansion and control joints, kitchen and bath. The reported BBP content in these products was 10 to 30 percent (Protecto Wrap, 2020), 15 to 40 percent (Tremco Canadian Sealants, 2015), 5 to 10 percent (Momentive, 2017), 5 to 10 percent (HCC Holdings Inc., 2015), and 7 to 13 percent (Wilsonart, 2013). Based on these data the weight fractions of BBP used in low-, medium-, and high-exposure scenarios were the minimum, average and maximum values of 0.05, 0.145, and 0.4, respectively. These products were assessed for both inhalation and dermal exposure.

Crafting Resin
One crafting resin product that may be used for home crafting such as model casting and mold production for resin and concrete projects was identified with reported BBP content of 5 to 15 percent (Smooth-On, 2022); the weight fractions of BBP used in low-, medium-, and high-exposure scenarios for this product were 0.05, 0.1, and 0.15 w/w. This product was assessed for both inhalation exposures for all life stages and dermal exposure for the cured solid version of the crafting resin for persons older than 3 years. Based on product use description the liquid crafting resin is mixed and cured within 10 to 20 minutes and gloves are recommended. Due to the short duration of use and the use of protective gloves, dermal exposure to the liquid crafting resin is not expected to occur. However, incidental contact during a spill may occur; therefore, EPA evaluated dermal contact to the liquid crafting resin for the product recommended mixing and curing duration.

Inks and Dyes
Two liquid pigment products were identified with BBP content. These included a liquid dye used to color crafting resins with reported BBP content of 30 to 60 percent (BJB Enterprises, 2019) and a stamp ink pad product with reported BBP content of 15 to 25 percent (Identity Group, 2017). Both products were modeled for dermal exposure only. Inhalation of BBP from the stamp ink pad is not expected to be significant due to the small surface area of the ink pad and small durations of expected use. For the crafting resin dye, the manufacturer website recommends adding the product to liquid resin at 1 to 5 percent of weight, resulting in a maximum diluted weight fraction of 3 percent BBP in the resin. Because this value is lower than BBP content in the previously described resin product, which was modeled for inhalation, it was not necessary to explicitly model resin pigment to capture potential for risk from inhalation.

Interior Car Care
One spray interior car cleaner product was identified with BBP content from a 2012 study on U.S. consumer products (Dodson et al., 2012). The measured BBP content was 0.0001 w/w and this weight fraction was used in low-, medium-, and high-exposure scenarios for this product. Inhalation and dermal exposures were assessed.

Paints and Coatings
A total of five paint and coating products with BBP content were identified. Three products were assessed quantitatively and two were assessed qualitatively and did not have significant potential for exposure. The qualitative assessed products were for a coating product for protecting spray paint booths with 2 percent BBP (W.M. Barr, 2015) and a touch-up paint pen for repairing paint chips and scratches on vehicles with 5 percent BBP (Ford Motor Company, 2019). The coating product for protecting spray paint booths was not assessed as consumers are unlikely to have spray paint booths in the home. The use of this product for off-label uses in home DIY projects was considered and deemed unlikely as it was only available in large format volumes and the cost was prohibitively expensive as compared to similar products specifically marketed for home DIY projects. Due to the nature of the product application method for the paint pen and anticipated infrequent use, none of the potential exposure routes were likely to result in significant exposure.

Among the quantitatively assessed paint and coating products, all were assessed for exposure by both inhalation and dermal exposure routes. Two of the products were modeled for indoor use. These products are a spray paint product with reported BBP content of 0.1 to 1 percent used for repairing or renewing surfaces such as bathtubs, sinks and vanities (Multi-Tech Products Corp, 2015), and a concrete sealant with reported BBP content of 0.1 to 1 percent. Consumer reviews on online retail sites report use of the concrete sealant for a variety of projects, including sealing and refinishing of fireplace stone,

concrete countertops, and floors. Weight fractions of 0.001, 0.0055, and 0.01 w/w were used in low-, medium-, and high-exposure scenarios for these products. The third quantitatively assessed product is an ultraviolet (UV light) and waterproof coating applied to exterior building surfaces; manufacturer suggested uses with potential relevance for home DIY repairs include application under roofing materials and structural facades. The BBP content reported for this product is 1 to 5 percent (Henry Company, 2015); BBP weight fractions used in low-, medium-, and high-exposure scenarios for this product were 0.01, 0.025, and 0.05 w/w.

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

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
				Inhalation [a]	Dermal	Ingestion		
						Suspended Dust	Settled Dust	Mouthing
Construction, paint, electrical, and metal products	Adhesives and sealants	Adhesives for small projects	Use of product in DIY small-scale home repair activities. Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Adhesives and sealants	Caulking products	Use of product in DIY home repair activities. Direct contact during use; inhalation of emissions during use	**QT**	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Adhesives and sealants	Patching and repair products for exterior repairs	Use of product in DIY small-scale home repair activities. Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Paints and coatings	Touch up auto paint	Paint is applied via a paint marker to small surface areas. No significant potential for exposure identified.	*QL*	*QL*	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Paints and coatings	Sealing and refinishing sprays (indoor use)	Use of product in DIY large-scale home repair activities. Direct contact during use; inhalation of emissions during use	**QT**	**QT**	*QL*	*QL*	*QL*
Construction, paint, electrical, and metal products	Paints and coatings	Sealing and refinishing sprays (outdoor use)	Use of product in DIY large-scale home repair activities. Direct contact during use; inhalation of emissions during use	**QT**	**QT**	*QL*	*QL*	*QL*
Furnishing, cleaning, treatment/care products	Fabrics, textiles, and leather products	Synthetic leather furniture	Direct contact during use; inhalation of emissions / ingestion of airborne particulate; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Furnishing, cleaning, treatment/care products	Fabrics, textiles, and leather products	Synthetic leather clothing	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Furnishing, cleaning, treatment/care products	Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles fabrics, textiles, and apparel	Vinyl flooring	Direct contact, inhalation of emissions / ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Other uses	Automotive products, fluids	Automotive lubricants	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Other uses	Automotive products, fluids	Interior car care	Direct contact during use; inhalation of emissions during use	**QT**	**QT**	*QL*	*QL*	*QL*

Consumer COU Category	Consumer COU Subcategory	Product/Article	Exposure Scenario and Route	Evaluated Routes				
				Inhalation [a]	Dermal	Ingestion		
						Suspended Dust	Settled Dust	Mouthing
Other uses	Automotive articles	Car mat	Direct contact during use. See routine contact scenario inhalation of emissions / ingestion of dust adsorbed chemical	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	*QL*
Other uses	Novelty articles	Adult toys	Direct contact during use; ingestion by mouthing	*QL*	**QT**	*QL*	*QL*	**QT**
Packaging, paper, plastic, hobby products	Ink, toner, and colorant products	Inks and dyes	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Packaging, paper, plastic, hobby products	Toys, playgrounds, and sporting equipment	Children's toys (legacy)	Collection of toys. Direct contact during use; inhalation of emissions / ingestion of airborne particulate; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Packaging, paper, plastic, hobby products	Toys, playgrounds, and sporting equipment	Children's toys (new)	Collection of toys. Direct contact during use; inhalation of emissions / ingestion of airborne PM; ingestion by mouthing	**QT** [b]	**QT**	**QT** [b]	**QT** [b]	**QT**
Packaging, paper, plastic, hobby products	Toys, playgrounds, and sporting equipment	Tire crumb, artificial turf	Direct contact during use (particle ingestion via hand-to-mouth)	**QT**	**QT**	**QT** [c]		
Packaging, paper, plastic, hobby products	Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	Small articles with the potential for semi-routine contact; packaging, including plastic bags and pouches; vinyl shelf liner, bottom surface of shoe, small exterior clothing components, disposable gloves	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*
Packaging, paper, plastic, hobby products	Arts, crafts, and hobby materials	Small articles with the potential for semi-routine contact; Modeling clay, jewelry making crafts	Direct contact during use	*QL*	**QT**	*QL*	*QL*	*QL*

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

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

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

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

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	Qualitative 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	Qualitative assessment done due to limited information on source attribution of the consumer COUs in landfills.

Environmental releases may occur from consumer products and articles containing BBP via their end-of-life disposal and demolition in the built environment or landfills, as well as from the associated down-the-drain release of BBP. It is difficult for EPA to quantify these end-of-life and down-the-drain exposures due to limited reasonably available information on source attribution of the consumer COUs. In previous assessments, EPA has considered down-the-drain analysis for consumer product scenarios where it is reasonably foreseen that the consumer product would be discarded directly down-the-drain. For example, adhesives, sealants, paints, coatings, cleaner, waxes, and polishes can be disposed down-the-drain while users wash their hands, brushes, sponges, and other product-applying tools. Although EPA acknowledges that there may be BBP releases to the environment via the cleaning and disposal of adhesives, sealants, paints, coatings, and cleaning and furnishing care products, the Agency did not quantitatively assess these products and instead provides a qualitative assessment. BBP-containing products can be disposed when users no longer have use for them, or they have reached the product shelf life and are taken to landfills. 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, sealants, paints, and coatings.

Section 3.2 in the *Environmental Media and General Population Exposure for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2024a) summarizes BBP monitoring data identified for landfills. Briefly, no studies were identified that reported the concentration of BBP in landfills or in the surrounding areas in the United States, but BBP was identified in sludge in wastewater plants in China, Canada, and the U.S. BBP is expected to have a high affinity to particulates (organic carbon-water partition coefficient [log K_{OC}] = 3.4–4.2) and organic media (octanol-water partition coefficient [log K_{OW}] = 4.7), which would cause significant retardation in groundwater and limit leaching to groundwater. Because of its high hydrophobicity and high affinity for soil sorption, it is unlikely that BBP will migrate from landfills via groundwater infiltration. Nearby surface waters however, may be susceptible to BBP contamination via surface water runoff if it is not captured before interacting with surface water.

2.2 Inhalation and Ingestion Modeling Approaches

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 BBP-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 BBP, 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 BBP).

CEM has capabilities to model exposure to BBP 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.

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 and article in instances where the prepopulated scenarios are not adequate. User inputs for physical and chemical properties of products and articles are utilized to calculate emission profiles of semi-volatile organic compounds (SVOCs). There are six emission calculation profiles within CEM (E1–E6) that represent specific use conditions and properties of various products and articles. A description of these models is summarized in the CEM user guide and associated appendices (accessed November 25, 2025).

CEM 3.2 estimates acute dose rates and chronic average daily doses for inhalation, ingestion, and dermal exposures of consumer products and articles. However, for the purpose of this assessment, EPA performed dermal calculations outside of CEM (see Section 1.1 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 life stages. EPA made some adjustments to match CEM's life stages to those listed in the Centers for Disease Control and Prevention (CDC) guidelines (CDC, 2021) and EPA's *A Framework for Assessing Health Risks of Exposures to Children* (U.S. EPA, 2006). CEM life stages are re-labeled from this point forward as follows:

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

Exposure inputs for these various life stages 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. 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- and far-field component 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 this activity pattern, 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 1×10^{-30} m^3/hour. In instances where a product might be used in several rooms of the house, air exchange rate was considered in the room of use to ensure that effects of ventilation were captured.

2.2.2 Inhalation and Ingestion Modeling for Articles

For articles, the model comprises an air compartment (including gas phase, suspended particulates) and a floor compartment (containing settled particulates). Semi-volatile organic compounds (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. Thus, the chemical transfer between particulates and the air phase is kinetically modeled in terms of the 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 the inhalation scenarios where DBP 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, transferring to particulates by partitioning, removal due to ventilation, removal due to cleaning of settled particulates and dust to which DBP has partitioned, and sorption or desorption to/from interior surfaces. The emissions from the article were modeled with a single exponential decay model. This means that the chronic and acute exposure

duration scenarios use the same emissions/air concentration data based on the weight fraction of the chemical in the article but have different averaging times. The acute data uses concentrations for a 24-hour period at the peak of the simulated emissions, while the chronic data was averaged over the entire 1-year period. Because air concentrations for most of the year are significantly lower than the peak value, the air concentrations 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 BBP consisted of both products and articles. The embedded models within CEM 3.2 that were used for BBP are listed in Table 2-3. 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, hence the A_ING2 Model was deemed inappropriate for estimating exposure for these COUs. Similarly, as described in Section 1, some solid articles and liquid products were not anticipated to contribute significantly to inhalation of BBP or ingestion of BBP sorbed to dust/PM and were therefore not modeled in CEM. Note that products and articles not assessed in CEM (synthetic leather clothing, adhesives for small projects, automotive lubricants, inks and dyes, patching and repair products for exterior surfaces, tire crumb, and small articles with potential for semi routine contact) are not listed in this table; exposure modeling for these items was performed outside of CEM as described in Sections 2.2 and 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	Sub-COU	Product/Article	Emission Model and Exposure Pathway(s)	CEM Saved Analysis
Construction, paint, electrical, and metal products	Adhesives and sealants	Caulking products	E1; P_INH2 (Near-field)	Caulk (fealant)
Construction, paint, electrical, and metal products	Paints and coatings	Sealing and refinishing sprays (indoor use)	E3; P_INH2 (Near-field, users), P_INH1 (bystanders)	Generic P3 E3
Construction, paint, electrical, and metal products	Paints and coatings	Sealing and refinishing sprays (outdoor use)	E3; P_INH2 (Near-field, users), P_INH1 (bystanders)	Generic P3 E3
Furnishing, cleaning, treatment/care products	Fabrics, textiles, and leather products	Synthetic leather furniture	E6; A_INH1, A_ING1, A_ING2, A_ING3	Leather furniture
Furnishing, cleaning, treatment/care products	Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles fabrics, textiles, and apparel	Vinyl flooring	E6; A_INH1, A_ING1, A_ING3	Plastic articles: vinyl flooring
Other uses	Automotive products, fluids	Interior car care	E3; P_INH2 (Near-field, users), P_INH1 (bystanders)	Generic P3 E3
Other uses	Automotive products, fluids	Interior car care	E6; A_INH1, A_ING1, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Other uses	Automotive articles	Car mat	No Emissions Modeled; A_ING2	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Packaging, paper, plastic, hobby products	Arts, crafts, and hobby materials	Crafting resin	E2; P_INH2 (Near-field, users), P_INH1 (bystanders)	Generic P2 E2
Packaging, paper, plastic, hobby products	Toys, playgrounds, and sporting equipment	Children's toys (legacy)	E6; A_INH1, A_ING1, A_ING2, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Packaging, paper, plastic, hobby products	Toys, playgrounds, and sporting equipment	Children's toys (new)	E6; A_INH1, A_ING1, A_ING2, A_ING3	Rubber articles: with potential for routine contact (baby bottle nipples, pacifiers, toys)
Products and articles not assessed in CEM (synthetic leather clothing, adhesives for small projects, automotive lubricants, inks and dyes, patching and repair products for exterior surfaces, tire crumb, and small articles with potential for semi routine contact) are not listed in this table; exposure modeling for these items was performed outside of CEM as described in Sections 2.2 and 2.4.				

In total, the specific products and articles representing four 6 COUs and 11 sub-COUs for BBP were mapped to 19 scenarios, 12 of which were modeled in CEM. Relevant consumer behavioral pattern data (*i.e.*, use patterns) and product-specific characteristics were applied to each of the scenarios and are summarized in Section 2.2.3.1 and Section 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 BBP in air and dust result in increased exposure. This may occur due to article specific characteristics that allow for higher emissions of BBP to air and/or environment specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control BBP emission rates from articles in CEM 3.2 models are weight fraction of BBP 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 BBP. 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-ingestion exposure in CEM (synthetic leather clothing, tire crumb rubber, and small articles with potential for semi-routine dermal contact) are not described here or included in the table. However, tire crumb rubber was assessed for inhalation exposure outside of CEM to accommodate use of empirical data for concentrations of BBP in air; details of this approach are provided in Section 2.4.

Weight fractions of BBP were calculated for each article as outlined in Section 2.1.1. Material density was assumed to be a standard value for PVC of 1.4 g/cm^3 in all articles. Values for article surface layer thickness were taken from CEM default values for scenarios with emissions from the same or similar solid material. CEM default values for parameters used to characterize the environment (use volume, air exchange rate, and interzonal ventilation rate) were used for all models.

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

Car Mats

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

Children's Toys

Children's toys generally have a small surface area for an individual item, but consumers may have many of the same type of item in a home. As phthalates are ubiquitous in PVC material, it is reasonable to assume that in a collection of toys all of the items may have BBP content. As such, surface area for these items was estimated by assuming that a home has several of these items rather than one. The surface area of new and legacy toys was varied for the low-, medium-, and high-exposure scenarios based on EPA's professional judgment of the number and size of toys collected in a bedroom. The low, medium, and high estimates, respectively, were based on 5 small toys measuring 15 cm × 10 cm × 5 cm, 20 medium toys measuring 20 cm × 15 cm × 8 cm, or 30 large toys measuring 30 cm × 25 cm × 15 cm.

Synthetic Leather Furniture

For textile furniture components, each scenario consisted of a couch and loveseat set, with the surface area varied in low-, medium-, and high-exposure scenarios to reflect the variability observed in standard sizes available for purchase. The low, medium, and high surfaces areas, respectively, are based on prisms measuring 60 × 30 × 25 inches, 80 × 36 × 30 inches, and 100 × 42 × 35 inches for a couch and 48 × 30 × 25 inches, 60 × 36 × 3 inches, and 72 × 42 × 35 inches for a loveseat. The measurements were compiled from furniture retail stores' descriptions. EPA added the low surface areas for a couch and

loveseat together to estimate exposures to smaller furniture in the low-end scenario, and similarly for the medium and high estimates. The Agency assumes the bottom side of the furniture is not covered with the same material.

Vinyl Flooring

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

Table 2-5. Summary of Key Parameters for Inhalation and Dust Ingestion Exposure to BBP 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 Volume (m^3) [d]	Interzone Ventilation Rate (m^3/h) [d]
Car mats	High	0.000050	1.4	1.29	0.01	Automobile	2.4	9.5
	Medium							
	Low							
Children's toys (legacy)	High	0.005000	1.4	9.45	0.01	Bedroom	36.0	107.01
	Medium	0.003000		2.32				
	Low	0.001000		0.28				
Children's toys (new)	High	0.001000	1.4	9.45	0.01	Bedroom	36.0	107.01
	Medium			2.32				
	Low			0.28				
Synthetic leather furniture	High	0.000652	1.4	17	0.01	Living Room	50.0	108.98
	Medium	0.000388		12				
	Low	0.000124		7.9				
Vinyl fooring	High	0.008900	1.4	202	0.01	Whole House	492.0	1.E−30
	Medium	0.004953		101				
	Low	0.000113		50.5				

[a] See Section 2.1.1 for weight fraction sources and discussion.
[b] Used density of PVC from various sources, see *BBP Consumer Exposure Analysis Spreadsheet* (U.S. EPA, 2025a).
[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] Legacy toys scenarios consider weight fractions in toys that are not limited to 0.1% and may be older than the 2017 CSPC phthalate rule, 16 CFR part 1307.
[g] New toys scenarios consider the application of the U.S. Consumer Product Safety Commission (CSPC) final phthalates rule established in 2017 (16 CFR 1307.3(a)) that limits children's toys and childcare articles from containing more than 0.1% of 5 phthalates, including BBP. The identified weight fractions in the legacy toys scenario were not limited to 0.1 %.

Environmental Parameters

The room of use selected for modeling affects the time occupants spend in the environment while products are actively emitting BBP, the total volume of air in the room, and ventilation rates. Default values are provided in CEM for use environment and ventilation rates in each room, which may be

modified by the user. Time spent in each use environment is defined by activity patterns as described in Section 2.2. For the articles assessed EPA used CEM defaults.

Mouthing Exposure

For mouthing exposure, key parameters include the rate of chemical migration from the article to saliva (µg/cm^2/h), 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 physical and chemical 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 composition of saliva. In addition, physical and chemical properties of the specific phthalate such as size, molecular weight, and solubility have a strong impact on migration rate to saliva.

Very little data was available for migration rates of BBP from solid articles to saliva, and none was found with weight fractions of BBP similar to those reported for the articles assessed here (<1% BBP by weight). As such, chemical migration rates of BBP were modeled with a theoretical framework based on physical and chemical properties of BBP and the solid matrix material. The model chosen for use was developed based on a regression model and validated against chemical migration rates for a wide range of chemical classes in several materials. This model estimates chemical material-specific chemical migration rates based on physical and chemical properties of BBP and parameters, which can be estimated based on the solid matrix material (Aurisano et al., 2022). The regression-based model takes the form in Equation 2-1:

Equation 2-1. Regression Model for Chemical Migration Rate from (Aurisano et al., 2022)

$$log_{10}R_{mgr} = 3.23 + 0.73log_{10}D_P + 0.92log_{10}C_0 - 0.0610log_{10}K_{OW}$$

Where:

R_{mgr}	=	Rate of chemical migration (µg/10 cm^2/min),
D_p	=	Solid phase diffusion coefficient (cm^2/s),
C_0	=	initial concentration of BBP in the solid matrix (µg/cm^2), and
K_{OW}	=	Octanol-water partitioning coefficient

Chemical-material specific values for the solid phase diffusion coefficient were estimated with a quantitative property-property relationship (QPPR) developed to predict diffusion coefficients for a wide range of organic chemicals and materials based on temperature, material type, and molecular weight of the chemical (Huang et al., 2017). This model was internally and externally validated against measured diffusion coefficients and shown to have good predictive capability for chemicals with molecular weights between 30 and 1178 g/mol at temperatures between 4 and 180 °C. The value calculated and used to assess mouthing exposure was 1.66×10^{-11} *cm^2/second.*

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 and a CEM default to estimate mouthing exposure in children (Danish EPA, 2010a; 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 cm^2 was thus chosen for all mouthing exposure models for children.

Mouthing of adult toys was only modeled for adults and teenagers. Object mouthing is not commonly observed behavior in adults and teens, and as such there are not standard values for mouthing surface area. To determine a reasonable value for mouthing surface area, EPA identified two studies that reported the surface area of the entire oral cavity in adults (Assy et al., 2020; Collins and Dawes, 1987). The mean surface area reported in Collins (1987) was 215 cm^2 and the mean value reported in Assy (2020) was 173 cm^2. Based on these data, EPA assumes approximately 200 cm^2 is a reasonable estimate for the total surface are in the oral cavity of an adult or teenager. However, this value accounts for all surface area—including teeth, gums, the ventral surface of the tongue, and mouth floor—which is a significant overestimation of surface area that would be in contact with an object. As such, it was assumed that 50 percent of the total surface area might reasonably represent mouthing surface area, and a value of 100 cm^2 was used for this parameter. This corresponds approximately with a one-ended cylinder having a radius of 2 cm and length of 7 cm. This value is similar, though slightly lower than the value of 125 cm^2 used for adult toy mouthing area in the ECHA assessment (ECHA, 2013).

Mouthing Duration: Mouthing durations were obtained from the EPA *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, mouthing duration values for toys were used to assess both legacy and new children's toys. Mouthing duration values for other objects were used for all other items assessed for mouthing by children (*i.e.*, synthetic leather furniture). The data provided in the *Exposure Factors 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* (U.S. EPA, 2011c) table 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 2-6. For mouthing of adult toys, values of 60, 30, and 15 minutes per day were used in the high-, medium-, and low-exposure scenarios, respectively. As there were no available data for these values, they were chosen to encompass the range of expected mouthing durations based on professional judgement.

Table 2-6. Mouthing Durations for Children for Toys and Other Objects

	Estimated Mean Daily Mouthing Duration Values from Table 4-23 in *Exposure Factors Handbook* (min/day)				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**	**Med.-Exposure Scenario**	**Low-Exposure Scenario**
Toy	1.0	28.3	39.2	23.07	39.2	22.9	1.0
Other object	5.2	12.5	24.5	16.42	24.5	14.7	5.2
Item Mouthed	**Reported Age Group**				**CEM Age Group: Infants 1–2 years**		
	12–15 Months	**15–18 Months**	**18–21 Months**	**21–24 Months**	**High-Exposure Scenario**	**Med.-Exposure Scenario**	**Low-Exposure Scenario**
Toy	15.3	16.6	11.1	15.8	16.6	14.7	11.1
Other object	12.0	23.0	19.8	12.9	23.0	16.9	12.0
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
Other object	21.8	15.3	10.7	10.0	21.8	14.4	10.0

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 BBP in air results in increased inhalation exposure. This may occur due to product formulation or use patterns that allow for higher emissions of BBP to air and/or environment specific characteristics such as smaller room volume and lower ventilation rates. Key parameters that control BBP emission rates from products in CEM 3.2 models are weight fraction of BBP 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.

Adhesives for small repairs products, assessed for dermal contact only see Table 2-1, which was evaluated outside of CEM. See Section 2.3 for a detailed description of dermal approach used to assessed dermal exposures, dermal data available, and parameterization of the selected approach. 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 2-7.

CEM default values for key parameters for exposure modeling including product mass used, duration of use, and frequency of use were not available for the specific products identified with BBP content. As such, values for these parameters were based on professional judgement, which incorporated information from product labels and technical specifications as well as information obtained from an informal survey of customer reviews on e-commerce sites. This information was synthesized to better understand how consumers use these products, and professional judgement was applied to develop specific values expected to capture a realistic range of values for each parameter. Product densities were taken from product specific technical specifications and SDSs, where possible. A detailed description of

derivations of key parameter values used in CEM Version 3.2 models for liquid and paste products is provided below, and a summary of values can be found in Table 2-7. Note that products not modeled for inhalation exposure are not included in Table 2-7.

Mass of Product Used

For products used for DIY home improvement and repair projects, the mass of product applied in each scenario was based on the reasonable assumption that the volume in which products are sold is adequate for the tasks they are intended for. All mass of product used inputs was based on a research of consumer available products fitting the COU description on manufacturers websites; see BBP Product Review tab (links and products available) in *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025a). This section summarizes the identified information for each product. Caulking products were sold in tubes ranging from 5.5 to 10.5 oz, The high exposure scenario assumed that the full 10.5-oz tube was used, reflecting scenarios where a large project or extensive application is undertaken. The medium- and low-exposure scenarios assumed that 5.25 and 2 oz were used, respectively, to represent smaller repair projects. Sealing and refinishing sprays used indoors were available in 12-oz, 1-gallon, and 5-gallon formats, and these volumes were used to calculate product mass used in low-, medium-, and high-exposure scenarios. The product for sealing outdoor surfaces was available only in 5-gallon containers; the high-exposure scenario assumed that the full volume was used, while the medium- and low-exposure scenarios assumed that one-half and one-quarter of the container were used.

For resin products used in DIY arts and crafts projects, an informal review of online community postings in model making forums and homemade products available on e-commerce platforms was conducted. This approach allowed for an understanding of how resins are commonly utilized in crafting, ensuring that the modeling assumptions align with practical usage patterns observed in these communities. Based on this information, resin casting and mold making projects may be performed across a variety of scales ranging from small models to furniture components and may be sold on e-commerce platforms after production. Given this wide range in usage, the same approach was taken as previously described for Automotive adhesives and products for home maintenance; high-, medium-, and low-exposure scenarios assumed that the whole container, half a container, and a quarter of a product container were used during each use event.

The interior car care product identified with BBP was not represented in CEM default scenario and there was no data available for specific or similar products in the *Exposure Factors Handbook*. As such, CEM default values for mass of product from the CEM Exterior Car Wax and Polish Scenario were applied; mass of product used in low-, medium-, and high-exposure scenarios was modeled as 100, 150, and 200 g in low-, medium-, and high-exposure scenarios. It was assumed that though product formulations differ (wipe-on vs. spray-on), use patterns would be similar and thus these values would be reasonable.

Duration of Use

Duration of use inputs was based on a survey of consumer available products fitting the COU description on manufacturers websites, see BBP Product Review tab (links and products available) in *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025a) and professional judgment. For auto care products, similar to amount of product used, for frequency of product use, it was assumed that though product formulations differ (wipe-on vs. spray-on), use patterns would be similar; thus, auto care products were modeled with one use per month. The duration of use was modeled as 15, 30, and 45 minutes.

For flooring adhesives products, large projects could be a full day of work, while smaller projects may be accomplished more quickly, so duration of use for high-, medium-, and low-exposure scenarios were assumed to be 480, 240, and 120 minutes. Caulking products are expected to be used in comparatively smaller scale projects and were thus modeled at use durations of 60, 30, and 15 minutes. Exposures to the liquid and solid cured form of the crafting resin were expected to occur during product mixing, curation, and craft painting and handling after cured. This exposure was assumed (professional judgment) and modeled at use durations of 120, 60, and 30 minutes for the high-, medium-, and low-intensity use scenarios, respectively.

Frequency of Use

The frequency of use input is used in the calculation of acute and chronic exposure durations. Acute exposures are for an exposure duration of 1 day and chronic exposures are for an exposure duration of 1 year. For flooring adhesives, given the significant work required to prepare and clean up after use as well as the relatively niche use, frequency of use of these products is not anticipated to be routine for consumers. The product is assumed to be used for a single project each year, which may take 2 days to complete. For caulking, crafting, and interior car care products, daily use was not considered likely, but the product could reasonably be used weekly during a period of extensive home renovations, crafting projects, and interior car care. Therefore, these products were modeled at a use frequency of 52 times per year. For all liquid and paste products, acute frequency was modeled as one use per day.

Environmental Parameters

The room of use selected for modeling affects the time occupants spend in the environment while products are actively emitting BBP, the total volume of air in the room, and ventilation rates. Default values are provided in CEM for use environment and ventilation rates in each room, which may be modified by the user. Time spent in each use environment is defined by activity patterns as described in Section 2.2 and cannot be modified for individual environments within CEM. As such, it is sometimes required to select an environment of use based on the activity pattern required and modify the environmental parameters to reflect conditions in the home area in which a product is expected to be used.

In this assessment, the majority of the products modeled used CEM defaults for all parameters in the specified room of use. However, for indoor floor refinishing products, the garage environment was selected as CEM activity patterns do not include any time in this room. This was chosen to reflect the fact that occupants are not expected to spend time in rooms with recently refinished floors outside of time spent actively applying the products. For this model, room volume and ventilation rates were changed from CEM default values for garage to CEM default values for living room as shown in Table 2-7.

Table 2-7. Summary of Key Parameters for Products Modeled in CEM 3.2

Product	Exposure Scenario Level [a]	Weight Fraction [b]	Density (g/cm^3) [c]	Duration of Use (min) [d e]	Product Mass Used (g) [d e]	Chronic Freq. of Use ($year^{-1}$) [d e]	Acute Freq. of Use (day^{-1}) [d e]	Use Environ.; Volume (m^3) [d g]	Air Exchange Rate, Zone 1 and Zone 2 (h^{-1}) [f]	Interzone Ventilation Rate (m^3/h) [g]
Sealants for small home repairs	H	0.400	4.9	120	19,873	2	1	Kitchen; 24	0.45	108.978
	M	0.175		60	5,713					
	L	0.050		30	407					
Flooring adhesive	H	0.050	1.1	480	19,873	2	1	Whole house; 492	0.45	1E−30
	M	0.038		240	5,713					
	L	0.025		120	407					
Caulking products	H	0.4	1.5	60	466	52	1	Bathroom; 15	0.45	108.978
	M	0.145		30	233					
	L	0.05		15	117					
Crafting resin	H	0.15	1.2	120	4,542	52	1	Utility room; 20	0.45	107.01
	M	0.1		60	2,555					
	L	0.05		30	568					
Interior car care product	H	0.0001	1.0	45	200	52	1	Garage; 90	0.45	108.978
	M	0.0001		30	150					
	L	0.0001		15	100					

[a] Exposure scenario levels are high- (H), medium-, (M), and low- (L) intensity uses.
[b] Weight fraction information is available in Section 2.1.2.
[c] From product SDS, see Section 2.1.2 for product specific references.
[d] From product use information provided by manufacturers, available in BBP Product Review tab in U.S. EPA (2025a).
[e] Based on product use descriptions, available in BBP Product Review tab in U.S. EPA (2025a).
[f] 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.
[g] CEM default.

2.3 Dermal Modeling Approach

This section summarizes the available dermal absorption data related to BBP, the interpretation of the dermal absorption data, dermal absorption modeling efforts, and uncertainties associated with dermal absorption estimation in Section 2.3. Dermal data were sufficient to characterize consumer dermal exposures to both liquids and solids containing BBP (Sections 2.3.2 and 2.3.2). Dermal exposures to vapors are not expected to be significant due to the extremely low volatility of BBP and therefore are not included in the dermal exposure assessment of BBP.

The rate of transport of BBP across the dermal barrier is considered flux-limited rather than delivery-limited. In brief, the physical and chemical properties of BBP (high molecular weight, large size, and low solubility in water) impede its ability to cross the dermal barrier, limiting the rate of flux independent of the concentration on the skin. The flux-limited screening dermal absorption approaches for liquid and solid products and articles assumes a constant rate of absorption of BBP in contact with the skin independent of concentration in the products and articles. Dermal modeling was done outside of CEM. CEM dermal modeling uses a dermal model approach that assumes infinite BBP migration from product to skin without considering saturation, which would result in greatly overestimations of dose and subsequent risk.

EPA used a computational approach outside CEM that bypassed the need for certain inputs required by CEM, like weight fractions and migration rates. For example, for liquid products, the concentration of BBP often exceeds its saturation concentration because BBP molecules form weak chemical bonds with polymer chains in the product/article, which favors migration out of the polymer. During direct dermal contact, BBP can migrate to the aqueous phase available in the skin surface or be weakly bound to the polymer. The fraction of BBP associated with polymer chains is less likely to contribute to dermal exposure as compared to the aqueous fraction of BBP because the chemical is strongly hydrophobic. As such, use of the CEM for dermal absorption, which relies on total concentration rather than aqueous saturation concentration, would greatly overestimate exposure to BBP in liquid chemicals.

2.3.1 Dermal Absorption Data

EPA identified four studies directly related to the dermal absorption of BBP in the literature. Of the four available studies, one study (DuPont, 2006a) was most reflective of BBP exposure from solid products and another (DuPont, 2006b) for consumer liquid products and formulations.

- Recent studies were preferred that used modern dermal testing techniques and guidelines. (Dupont et al. (2006b) vs. Elsisi et al. (1989)).
- Studies of human skin were preferred over animal models, and when studies with human skin were not suitable (see other criteria), studies of guinea pig skin were preferred over rat studies. Guinea pig skin absorption is closer to human skin than rats. (DuPont (2006b) is a human study; Elsisi et al. (1989) is a rat study).
- Studies of full skin thickness were preferred over studies of just the stratum corneum (SC). Generally, studies should provide information on dermatoming methods and ideally provide a value for thickness.
- *In vivo* or freshly excised (non-frozen) human skin studies were preferred, provided there was not a significant delay between skin sample retrieval and assay initiation. (DuPont (2006b) is an *in vitro* human study; Elsisi et al. (1989) is an *in vivo* rat study).
- Studies using an aqueous vehicle type were preferred over neat chemical studies because there is greater relevance to consumer product formulations and subsequent exposure, and due to greater

uncertainties from neat chemical resulting in lower absorptions than formulations that may enhance dermal absorption.
- Studies with reported sample temperatures that represent human body temperature in a humidity-controlled environment were preferred.
- Studies with a more reflective exposure duration to the target exposure scenario were preferred. (DuPont (2006b) was preferred over Elsisi et al. (1989) as it is an 8-hour exposure vs. 7 days).

Information on the toxicokinetics of dermal BBP exposure is limited, as EPA identified two *in vivo*/*ex vivo* rodent studies (Sugino et al., 2017; Elsisi et al., 1989) and three *in vitro* human study evaluating absorption, distribution, metabolism, and excretion (ADME) properties following dermal application (Sugino et al., 2017; DuPont, 2006a, b).

In the report by Elsisi et al. (1989), ADME (*i.e.*, adsorption, distribution, metabolism, and elimination) properties of eight phthalates, including BBP, were analyzed through dermal application of radiolabeled parent compounds in male F344 rats. ^{14}C-BBP (5–8 mg/cm^2) was applied to shaved dorsal area skin (1.3-cm diameter application area) and covered with a plastic cap and urine and feces were collected every 24 hours for 7 days. By end of assessment, approximately 30 percent of ^{14}C-BBP was excreted through the urine and feces while most of the un-excreted dose remained at the site of application (44.9%). Relative to other phthalates tested, BBP had a linear and intermediate excretion rate with slower absorption and excretion likely being due to its higher molecular weight; in comparison, other medium-chain phthalates with a low molecular weight (*e.g.*, dibutyl phthalate [DBP]) showed rapid excretion. Elsisi et al. (1989) also observed low levels of distribution in muscle (4.6%), adipose (0.17%), and small amounts across brain, lung, liver, spleen, small intestine, kidney, testis, spinal cord, and blood (summation of <0.5%). Thus, in addition to biliary excretion and enterohepatic recirculation, BBP metabolites may distribute into multiple non-circulatory or non-hepatic compartments following dermal exposure. However, as with oral exposure studies noting relatively short BBP metabolite half-lives in both rats and humans (Anderson et al., 2001; Nativelle et al., 1999; Eigenberg et al., 1986), it is assumed that BBP metabolites do not accumulate in tissues.

Sugino et al. (2017) used *in vitro* epidermal membranes (0.95 cm^2) prepared from abdominal excisions of male hairless rats (WBN/Ila-Ht) and human females to assess skin permeation properties of multiple phthalates, including BBP. Application of BBP to skin showed species-specific metabolite permeation outcomes, but no diffusion of the parent compound. In sections prepared from hairless rats, only the monoester metabolites monobutyl phthalate (MBP) and monobenzyl phthalate (MBzP) diffused across dermal membranes, with more MBP metabolites relative to MBzP. Conversely, MBzP was the dominant metabolite recovered in human skin, and the permeability coefficient was markedly lower in human skin relative to the rat. An additional important finding of this *in vitro* assessment is that there also appeared to be metabolism-dependent processes impacting dermal uptake. Sugino et al. (2017) applied diisopropyl fluorophosphates (DFP), as serine-esterase inhibitor, to additional rat skin treatment groups and noted both a shift toward MBzP metabolite production and impermeability of BBP metabolites following DFP application.

Lastly, Dupont et al. (2006a, b) conducted two independent assessments using *in vitro* human abdominal skin sections. The first experiment utilized skin collections (468–487 µm thick) and exposed 0.64-cm^2 size sections to an infinite dermal load of 100 µL/cm^2 BBP for 8 hours, which was spiked with ^{14}C-BBP (for recovery estimate) into a non-radiolabeled formulation that was uniformly mixed. Recovery of the non-absorbed applied dose at the end of 8 hours was 96.4 percent, with a total estimated absorbed dose of 0.197 percent (165 µg BBP) (DuPont, 2006b). The second experiment by Dupont et al. (2006a) exposed 0.64 cm^2 abdominal skin sections (248–470 µm thick) to a BBP film matrix containing ^{14}C-BBP-occluded Parafilm directly placed on the skin for 8 hours. In this case, the total estimated exposure

was 5,958 µg BBP, and the total absorbed dose at the end of 8 hours was less than 0.01 percent (0.57 µg BBP).

Although human dermal evidence is limited, EPA assumes that BBP dermal absorption is low, and that dermal migration is reportedly lower in human skin compared to rat skin (Sugino et al., 2017; Scott et al., 1987). This assumption, along with the lack of data and uncertainty in available studies, has led several agency assessments to adopt a worst-case scenario dermal bioavailability of 5 percent in humans (NICNAS, 2015; ECJRC, 2007).

For the specific assessment of exposure to BBP from contact of adult toys with mucosal membranes, EPA considered Britz et al. (1980), as suggested by the Science Advisory Committee on Chemicals (U.S. EPA, 2025e). This study provides some insight on the differences in absorption between skin types. Britz et al. (1980) provided a comparison of absorption of hydrocortisone in the forearm compared to the vulvar skin (labia majora) of five women. The urinary excretion of radiolabeled hydrocortisone percent dose was larger for vulvar skin than for forearm skin for exposures measured at 6, 12, and 24 hours. The vulvar skin percent of dose rapidly decreased until it was comparable yet higher to forearm absorption after 3 days. This study indicates that vulvar skin may have higher absorption than forearm skin. However, the study results showed high inter-individual variability of absorption. In addition, the shortest exposure duration experiment in the study was for 0 to 6 hours, which is much higher than the exposure duration used for adult toys in this assessment (15, 30, and 60 minutes; see Table 2-8 for details).

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

2.3.2 Flux-Limited Dermal Absorption for Liquids

Using the Dupont (2006b) estimate of 0.165 mg on a 0.64-cm^2 area of BBP (0.258 mg/cm^2) over an 8-hour period, the steady-state flux of neat BBP is estimated as 3.22×10^{-2} $mg/cm^2/h$. EPA assumed the steady-state flux is equal to the average flux.

2.3.3 Flux-Limited Dermal Absorption for Solids

Using the Dupont (2006a) estimate of 0.00057 mg over a 0.64 cm^2 area of BBP (0.0008906 mg/cm^2 of BBP) over an 8-hour period, the steady-state flux of neat BBP is estimated as 1.113×10^{-4} $mg/cm^2/h$. In the experimental set up, Dupont et al. (2006a) collected receptor fluid to ensure the concentration of the BBP in the receptor fluid did not exceed 10 percent of its maximum solubility at 0.5, 1, 4, and 8 hours but the absorption experiment was for 8 hours. EPA estimated the steady-state flux and assumed it is equal to the average flux.

2.3.4 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 2-8. 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, and more scenario- and chemical-specific inputs are needed in Section 4 of the *Risk Evaluation for Benzylbutyl Phthalate (BBP)* (U.S. EPA, 2025d). For items that were considered to have a high level of uncertainty or potential variability, different surface areas were assumed in high-, medium-, and low-exposure scenarios. The subsections followingr Table 2-8 provide details on assumptions used to derive other key parameters. Calculations, sources, input parameters and results are also available in *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025a).

Table 2-8. Key Parameters Used in Dermal Models

Product	Scenario	Duration of Contact (minutes)	Chronic Frequency of Contact (year $^{-1}$)	Acute Frequency of Contact (day $^{-1}$)	Dermal Flux (mg/cm^2/hour) [a]	Contact Area
Adult toys	High	60	365	1	1.11E−04	Inside of 2 hands (palms, fingers)
	Medium	30			1.11E−04	
	Low	15			1.11E−04	
Car mats	High	60	52	1	1.11E−04	10% of hands (some fingers)
	Medium	30			1.11E−04	
	Low	15			1.11E−04	
Children's toys (legacy)	High	137	365	1	1.11E−04	Inside of 2 hands (palms, fingers)
	Medium	88			1.11E−04	
	Low	24			1.11E−04	
Children's toys (new)	High	137	365	1	1.11E−04	Inside of 2 hands (palms, fingers)
	Medium	88			1.11E−04	
	Low	24			1.11E−04	
Clothing (synthetic leather)	High	480	52	1	1.11E−04	50% of entire body surface area
	Medium	240			1.11E−04	25% of face, hands, and arms
	Low	120			1.11E−04	Inside of 2 hands (palms, fingers)
Furniture (synthetic leather)	High	480	365	1	1.11E−04	50% of entire body surface area
	Medium	240			1.11E−04	25% of face, hands, and arms
	Low	120			1.11E−04	Inside of 2 hands (palms, fingers)
Small articles with potential for semi-routine contact	High	120	365	1	1.11E−04	Both hands (entire surface area)
	Medium	60			1.11E−04	Inside of 2 hands (palms, fingers)
	Low	30			1.11E−04	10% of hands (some fingers)
Vinyl flooring	High	120	365	1	1.11E−04	Both hands (entire surface area)
	Medium	60			1.11E−04	Inside of 2 hands (palms, fingers)
	Low	30			1.11E−04	10% of hands (some fingers)
Adhesives for small projects	High	60	52	1	3.23E−02	10% of hands (some fingers)
	Medium	30			3.23E−02	
	Low	15			3.23E−02	

Product	Scenario	Duration of Contact (minutes)	Chronic Frequency of Contact (year $^{-1}$)	Acute Frequency of Contact (day $^{-1}$)	Dermal Flux (mg/cm^2/hour) [a]	Contact Area
Automotive lubricants	High	120	1	1	3.23E−02	10% of hands (some fingers)
	Medium	60			3.23E−02	
	Low	30			3.23E−02	
Caulking products	High	60	12	1	3.23E−02	Inside of 2 hands (palms, fingers)
	Medium	30			3.23E−02	Inside of 1 hand (palms, fingers)
	Low	15			3.23E−02	10% of hands (some fingers)
Crafting resin (liquid)	High	20	52	1	3.23E−02	10% of hands (some fingers)
	Medium	15			3.23E−02	
	Low	10			3.23E−02	
Crafting resin (cured)	High	120	52	1	1.11E−04	Inside of 2 hands (palms, fingers)
	Medium	60			1.11E−04	Inside of 1 hand (palms, fingers)
	Low	30			1.11E−04	10% of hands (some fingers)
Inks and dyes	High	15	52	1	3.23E−02	Inside of 2 hands (palms, fingers)
	Medium	10			3.23E−02	Inside of 1 hand (palms, fingers)
	Low	5			3.23E−02	10% of hands (some fingers)
Interior car care	High	45	52	1	3.23E−02	Inside of 2 hands (palms, fingers)
	Medium	30			3.23E−02	Inside of 1 hand (palms, fingers)
	Low	15			3.23E−02	10% of hands (some fingers)
Patching and repair products for exterior surfaces	High	120	2	1	3.23E−02	Inside of 2 hands (palms, fingers)
	Medium	60			3.23E−02	Inside of 1 hand (palms, fingers)
	Low	30			3.23E−02	10% of Hands (some fingers)
Sealing and refinishing Sprays (indoor use)	High	480	2	1	3.23E−02	10% of hands (some fingers)
	Medium	240			3.23E−02	
	Low	120			3.23E−02	
Sealing and refinishing sprays (outdoor use)	High	480	2	1	3.23E−02	10% of hands (some fingers)
	Medium	240			3.23E−02	
	Low	120			3.23E−02	

[a] See Section 2.3.3 and *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Exposure Analysis* (U.S. EPA, 2025a).

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 as described in Section 2.2.3.2. For products not modeled in CEM (adhesives for small projects, automotive lubricants, and inks and dyes), values for contact time were estimated based on professional judgement, which incorporated information from product labels and technical specifications as well as

information obtained from an informal survey of customer reviews on e-commerce sites. In each case, while direct contact with the product (actual use duration) is expected to be very short, reasonably foreseeable circumstances exist under which the user may not wash the products off their hands immediately, resulting in a longer exposure time. For adhesives for small projects the products may be used several times over a longer duration. Since the small project can include a wide range of durations, EPA considered repair products requiring adhesive in multiple locations or applications. The consideration of repetitive small projects high-, medium-, and low-contact durations of 60, 30, and 15 minutes were chosen. For inks and dyes, stamps may be used multiple times on duplicate documents or resin pigment may be left on hands while the resin is mixed and poured; to reflect this possibility, high-, medium-, and low-contact durations of 15, 10, and 5 minutes were chosen. In the case of automotive lubricants, the product may remain on the skin until the larger project is complete, which may entail multiple repair tasks or reassembly/reinstallation of auto parts. As such, high-, medium-, and low-contact durations were assumed to be 120, 60, and 30 minutes for auto lubricants, respectively.

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 vinyl flooring, values for dermal contact time are based on EPA's *Standard Operating Procedures for Residential Pesticide Exposure Assessment* for the high exposure level (2 hours; time spent on floor surfaces), ConsExpo for the medium exposure level (1 hour; time a child spends crawling on treated floor), and professional judgement for the low exposure level (0.5 hours) (U.S. EPA, 2012). Clothing and indoor furniture have the potential for long durations of dermal contact but may be also used for shorter periods and were thus modeled at 480, 240, and 120 minutes. Contact durations of 60, 30, and 15 minutes were assigned to car mats, which are assumed to have contact primarily during cleaning. To estimate contact time with children's toys, data were 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.

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

In addition to the scenarios for dermal exposure to BBP from specific articles, a scenario was modeled in which consumers may have semi-routine contact with one or more small items containing BBP. A complete list of articles and associated COUs modeled under this scenario is outlined 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 number and variety of small items identified with BBP content, EPA considers it reasonable to assume that an individual could have significant daily contact with some combination of these items and/or with other similar items that have not been measured during monitoring campaigns. As such, articles modeled under this scenario were assumed to have dermal contact times of 120, 60, and 30 minutes per day.

Range for 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 products not modeled in CEM, inks and dyes and small project adhesives were assumed to be used once per week, while automotive lubricants were assumed to be used once per year.

For articles, assumptions about frequency of contact 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 *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2025d)). For articles that are expected to be used or touched on a routine basis, such as children's toys, furniture, vinyl flooring, and adult toys, contact was assumed to be once per day every day. Recognizing that for adult toys daily use may be an upper bound or overestimation.

BBP is expected to be present in polyurethane (PU) leather garments, which are not expected to be worn daily but could reasonably be worn on a routine basis. As such, dermal contact with clothing was modeled as once every week. Car mats were modeled as a single contact event each week, to represent an individual who does a weekly car cleaning.

2.4 Tire Crumb Rubber Modeling

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

All calculations are provided in *Consumer Exposure Analysis for Butyl Benzyl Phthalate (BBP)* (U.S. EPA, 2025a).

2.4.1 Tire Crumb Inhalation Exposure

Air samples were collected for SVOC analysis without a size-selective particle inlet to allow both vapor- and particle-phase SVOCs to be collected simultaneously. Separate particle- and gas-phase air concentrations were not measured. However, as previously discussed, BBP is more likely to be present in particulates rather than gaseous phase. As such, it is unlikely that inhaled BBP will be fully absorbed after inhalation and the fraction absorbed was estimated to be 0.7. This was the recommended value in the exposure characterization (U.S. EPA, 2024b) and likely represents a health-protective estimate given the slow rate of diffusion through solid media for BBP and low solubility in aqueous fluids, which would limit partitioning to lung fluids. The inhaled dose per event is defined as follows:

Equation 2-2. Inhalation Dose Per Exposure Event

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

Where:

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

Age-stratified inhalation rates during high intensity activity were taken from Table 6-2 of the *Exposure*

Factors Handbook. Body weight values were the same as those used in CEM. Exposure time was assumed to be 1 hour for children aged less than 11 years, 3 hours for teens 11 to 16 years, and 2 hours for older teens and adults.

2.4.2 Tire Crumb Dermal Exposure

Dermal exposure to tire crumb was assessed under the assumption of dermal adherence during play and subsequent absorption. The 10th, 50th, and 90th percentile measurements of BBP in tire crumb samples were used in low-, medium-, and high-exposure scenarios, respectively. The fraction of BBP absorbed from each event was assumed to be 10 percent as recommended in the exposure characterization (U.S. EPA, 2024b). It is likely that this value somewhat overestimates exposure given that uptake of BBP is expected to be flux-limited. However, a flux-based value could not be calculated as there were no data available to estimate total contact area of the particulate matter adhered to skin and the assumption of 10 percent absorption is expected to provide a reasonable, health-protective estimate. Dermal dose per exposure event was defined as follows:

Equation 2-3. Dermal Dose Per Exposure Event

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

Where:

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

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

Values for dermal adherence to skin were obtained from (U.S. EPA, 2011b). Only values for adherence of solids to skin after playing sporting events on tire crumb fields was used in this assessment; the upper and lower boundaries of the 95 percent confidence interval were used in high- and low-exposure scenarios, respectively. The geometric mean reported value was used in the medium- exposure scenario.

2.4.3 Tire Crumb Ingestion Exposure

The same values of BBP content in solid particles described in Section 2.4.1 were used to estimate exposure by inadvertent ingestion during play. The absorption fraction of 50 percent recommended in the exposure characterization was used (U.S. EPA, 2024b). Ingestion dose per exposure event was then calculated as follows:

Equation 2-4. Ingestion Dose Per Exposure Event

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

Where:

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

Age-stratified ingestion rates were taken from *Exposure Factors Handbook* Table 5-1.

2.4.4 Tire Crumb Acute and Chronic Dose Calculation

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

Equation 2-5. Chronic Average Daily Dose (CADD)

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

Where:

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

Equation 2-6. Acute Dose Rate (ADR)

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

Where:

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

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

2.5 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 2-5 for inhalation and Table 2-8 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 A.3).

Table 2-9. Intermediate Event per Month and Day Inputs

Product	Events per Day[a]	Events per Month[a]
Patching and repair products for exterior surfaces	1	2
Sealing and refinishing sprays (indoor use)	1	2
sealing and refinishing sprays (outdoor use)	1	2

[a] Events per day and month values determined using professional judgement based on manufacturer product description use.

3 CONSUMER EXPOSURE RESULTS

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

3.1 Acute Dose Rate Results, Conclusions and Data Patterns

Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Risk Calculator (U.S. EPA, 2025c) summarizes the high-, medium-, and low-acute dose rate results for all life stages from CEM modeling for inhalation and ingestion exposures as well as computational modeling for all dermal exposures. Products and articles marked with a dash (–) did not have dose results because the product or article was not evaluated quantitatively; see Section 2.1 for discussion about qualitative assessments and rational for not evaluating certain exposure routes. Dose results applicable to bystanders are highlighted. Bystanders are people who are not in direct use or application of a product but can be exposed to BBP 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 life stage could reasonably be either a product user or bystander, the user scenario inputs were selected as proximity to the product during use would result in larger exposure doses as compared to a bystander. The main purposes of *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Risk Calculator* (U.S. EPA, 2025c) is to summarize acute dose rate results, show which products or articles did not have a quantitative result and show which results are used for bystanders. Data patterns are illustrated in figures and descriptions of the patterns by exposure route and population or life stage are summarized in this section.

Figure 3-1 through Figure 3-6 show acute dose rate data for all products and articles modeled in all life stages assessed. The figures show ADR estimated from exposure via inhalation, ingestion (aggregate of mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact. Among the younger life stages, there was no clear pattern that showed a single exposure pathway most likely to drive exposure. However, for teens and adults, dermal contact was a strong driver of exposure to BBP, with the dose received being generally higher than the dose received from exposure via inhalation or ingestion—with the exception of the vinyl flooring exposure scenarios and the legacy toys high-end exposure scenario where inhalation drove exposure.

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. The acute dose rate for some products/articles covers a larger range than others primarily due to a wider distribution of BBP weight fraction values and behavioral factors such as duration of use or contact time and mass of product used as described in Section 2.2. Key differences in exposures among life stages include (1) designation as product user or bystander; (2) behavioral differences such as mouthing durations, hand-to-mouth contact times, and time spent on the floor; and (3) dermal contact expected from touching specific articles that may not be appropriate for some life stages. For purposes of this risk evaluation, EPA assumed that the absorptive flux of BBP for solid and liquid products serves as an upper bound and assumes an excess of BBP in contact with the skin independent of concentration in the article. For this reason, products with similar use patterns and dermal skin contact inputs but differing BBP content have the same exposure dose

results. Figures and observations specific to each life stage are below.

Infants, Toddlers, Preschoolers, and Middle Childhood (1–10 Years)

Figure 3-1 show all exposure routes for infants aged less than a year and toddlers 1 to 2 years old. Figure 3-2 show all exposure routes for preschoolers ages 3 to 5 years and middle childhood children aged 6 to 10 years. Exposure patterns were very similar for products or articles and routes of exposure across these four life stages. Ingestion route acute dose results in the figures show the sum of all ingestion scenarios (mouthing, suspended dust, and surface dust) when applicable for that scenario (see Table 2-1). Inhalation exposures consider suspended dust that has been in direct contact with the article and is then resuspended, or gas phase emissions that partition to suspended dust.

The acute dose values of BBP from exposure to consumer products and articles are driven primarily by dermal exposures. Dermal ADR values are higher; for example, in crafting resins, furniture (synthetic leather), and new children's toys. In other scenarios, like vinyl flooring, inhalation is higher. For legacy children's toys, dermal exposure is the driver except for the high-end exposure scenario where inhalation is the driver.

In the case of vinyl flooring and legacy children's toys, the higher inhalation dose is due to larger BBP weight fractions than in other articles. Dermal exposure differences among scenarios are driven mainly by the exposure duration, frequency of the contact, and exposed dermal surface area. Crafting resins, and furniture (synthetic leather) dose values were higher mainly because these scenarios used contact durations longer than the other dermal scenarios: 0.5 to 2 hours per event for crafting resins and 2 to 8 hours per event for furniture (synthetic leather) textiles for low- to high-intensity use scenarios.

The highest acute dose for these age groups is from dermal exposure to crafting resin, followed by inhalation from sealing and refinishing sprays, followed by inhalation from vinyl flooring. Inhalation doses of adhesives and sealants for these life stages represent bystander exposures, which is a person in the proximity of someone else using such products. These inhalation doses from these products (crafting resins, sealing and refinishing sprays) are higher than certain articles assessed for indoor inhalation of suspended dust, like children's toys and furniture (synthetic leather) and lower for vinyl flooring suspended dust inhalation doses. The differences are driven by BBP weight fractions and total surface area of articles and indoor presence. For example, vinyl flooring surfaces are much larger than the surface area covered by toys, furniture (synthetic leather), and smaller or less numerous articles, in addition to vinyl flooring having larger weight fractions as well.

Unless specified, ingestion doses are the combination of ingestion of suspended dust, settled dust, and mouthing. Not all three ingestion routes were assessed for every article; see Table 2-1 for ingestion routes considered for each exposure scenarios and articles. Ingestion of BBP has the overall lowest doses across scenarios except for vinyl flooring that was assessed for ingestion of suspended and settled dust. For articles assessed for mouthing (in additon to suspended and settled dust), such as toys and furniture textiles, exposure from mouthing is expected to have a larger impact on the overall ingestion dose because mouthing is a direct exposure. However, ingestion of settled dust had a larger impact on the overall ingestion doses (see Figure 3-3 and Figure 3-4). Mouthing tendencies decrease or cease entirely for children 6 to 10 years old; thus, there is no mouthing influence on ingestion doses for ages above 6 years old. Articles that were not assessed for mouthing were assessed for ingestion of settled and suspended dust, in which the settled dust exposures tend to be larger than ingestion from suspended dust.

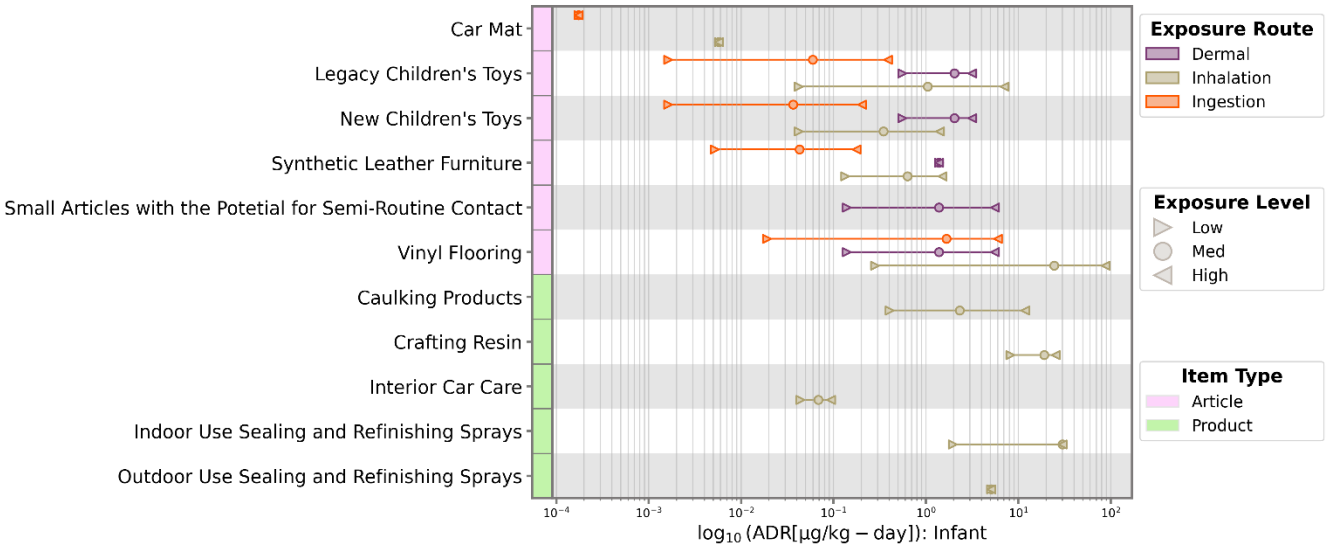


Figure 3-1. Acute Dose Rate for BBP from Ingestion, Inhalation, Dermal Exposure Routes for Infants (<1 Year) and Toddlers (1–2 Years)

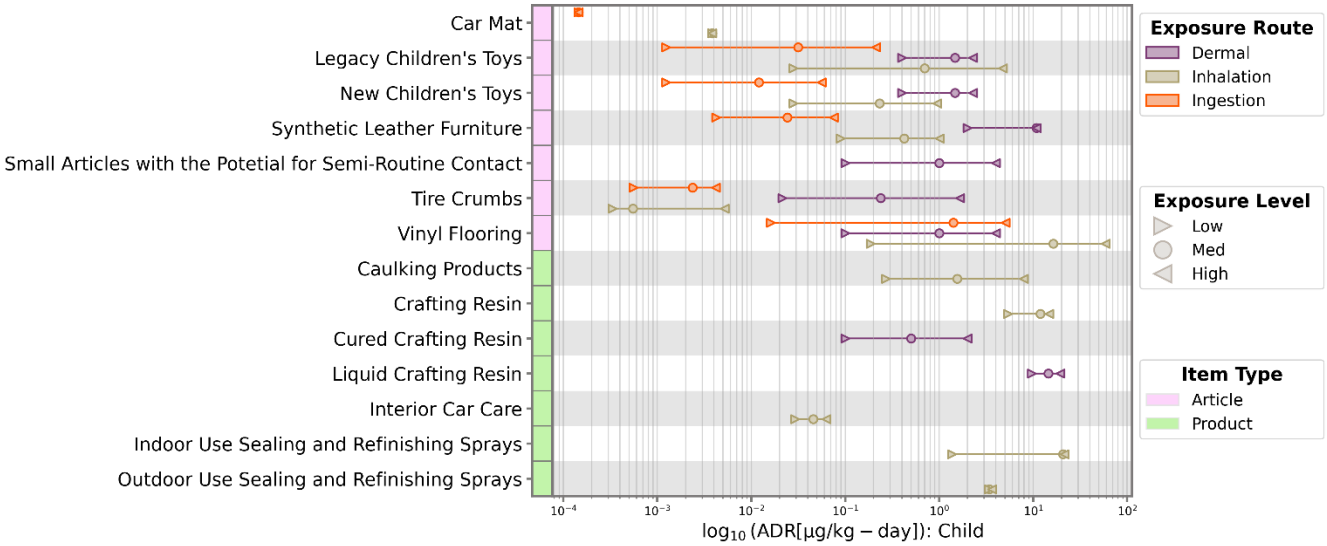


Figure 3-2. Acute Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

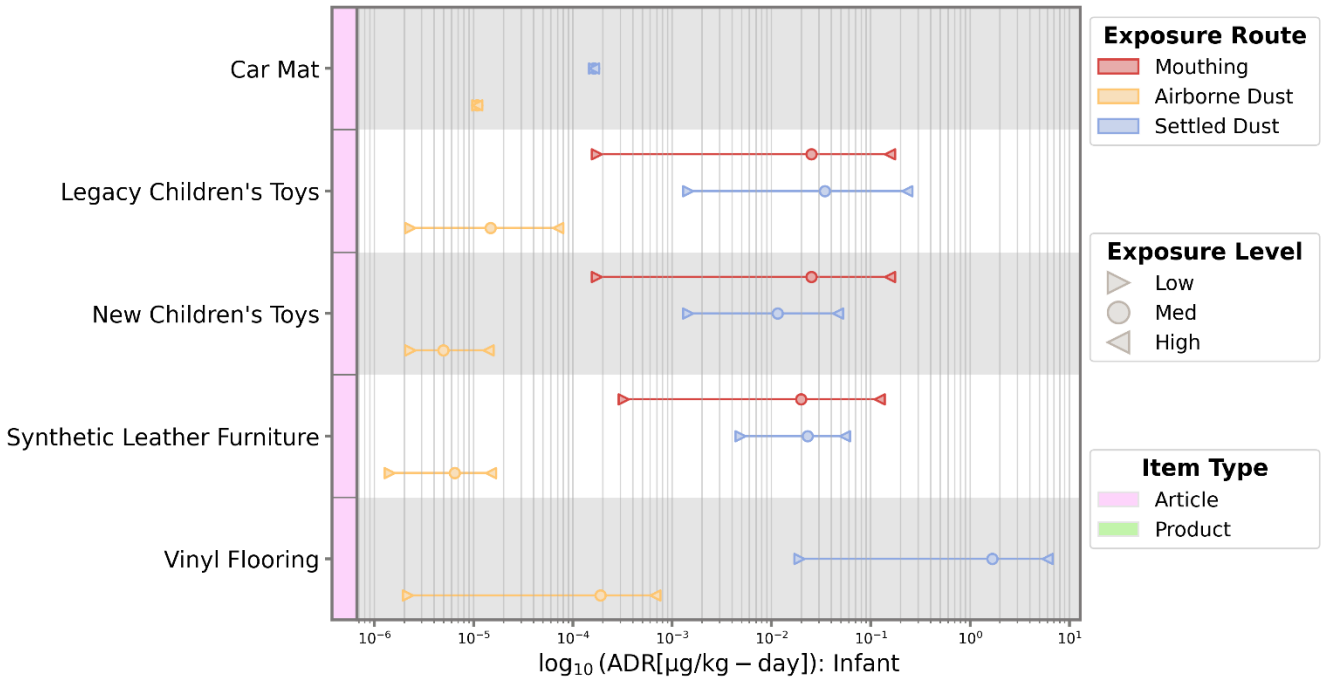


Figure 3-3. Acute Dose Rate of BBP from Suspended and Settled Dust Ingestion and Mouthing for Infants (<1 Year)

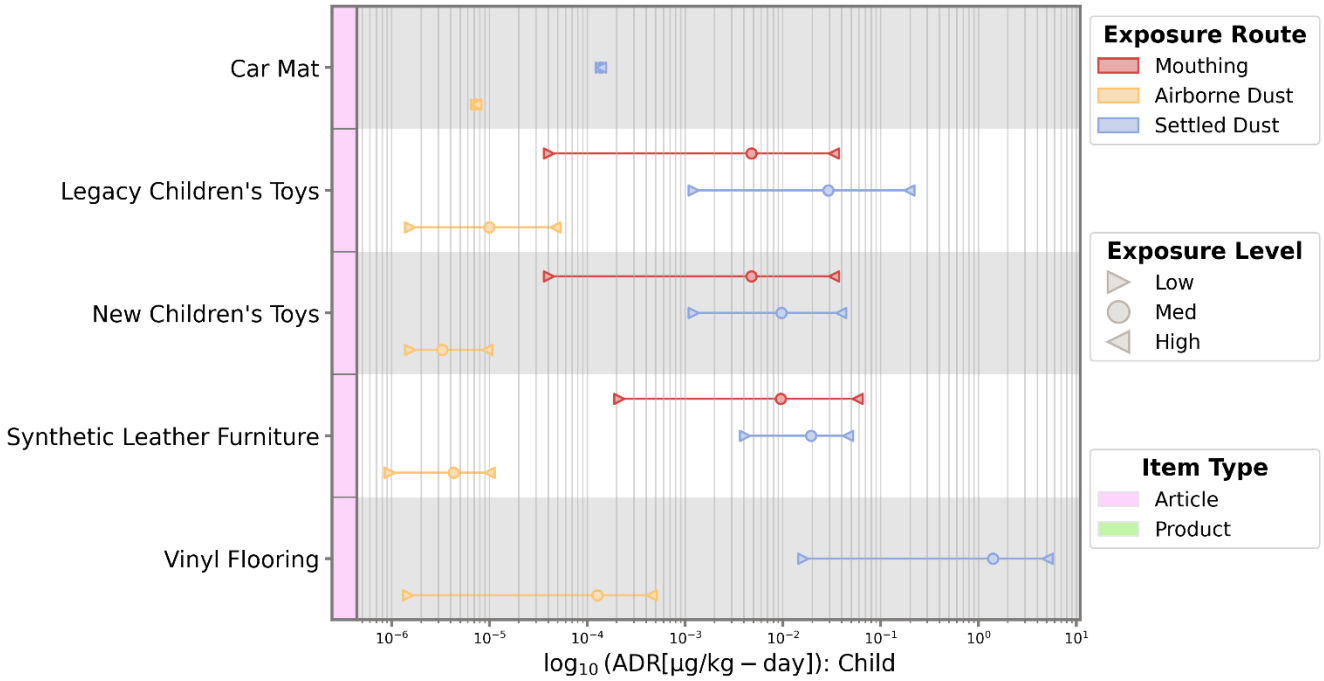


Figure 3-4. Acute Dose Rate of BBP from Suspended and Settled Dust Ingestion and Mouthing for Preschoolers (3–5 Years)

Young Teens, Teenagers, Young Adults, and Adults (11–21 Years and 21+ Years)
Figure 3-5 show all exposure routes for young teens (11–15 years) and teenagers and young adults (16–20 years) combined. Figure 3-6 shows all exposure routes for adults above 21 years old. Exposure

patterns were very similar for all products and articles and routes of exposure in these three life stages. The acute dose rate for some products and articles covers a larger range than others primarily due to a wider distribution of weight fraction values for toys, furniture components, and vinyl flooring. Inhalation exposure as a bystander for these life stages was not evaluated for adhesives and sealants. Teenagers and young adults (16–20 years) can use adhesives and sealants products in a similar capacity as adults during DIY projects; hence, this life stage was modeled as a user of the product rather than a bystander. Users have higher exposure doses when considering direct contact and use. Dermal exposure resulted in the highest doses overall except for vinyl flooring inhalation doses, which were higher than all doses across scenarios.

For articles considered in the indoor assessment, dermal doses were generally higher than inhalation and ingestion of suspended and settled dust for car mats, new children's toys, furniture components, and tire crumb (except for vinyl flooring and legacy children's toys). For vinyl flooring and legacy children's toys, inhalation and dermal medium- and high-intensity use exposure doses were similar. Ingestion had lower doses for the medium- and low-intensity use exposure scenarios. The scenarios with higher inhalation doses are driven by larger weight fractions in comparison to other articles.

Ingestion via mouthing is not considered for these life stages, which is expected due to a decrease or ceased in mouthing behavior (except for adult toys). Ingestion of settled dust is the highest ingestion pathway for products and articles; see Figure 3-7 that suggests that indoor dust ingestion can be an important contributor to BBP exposures.

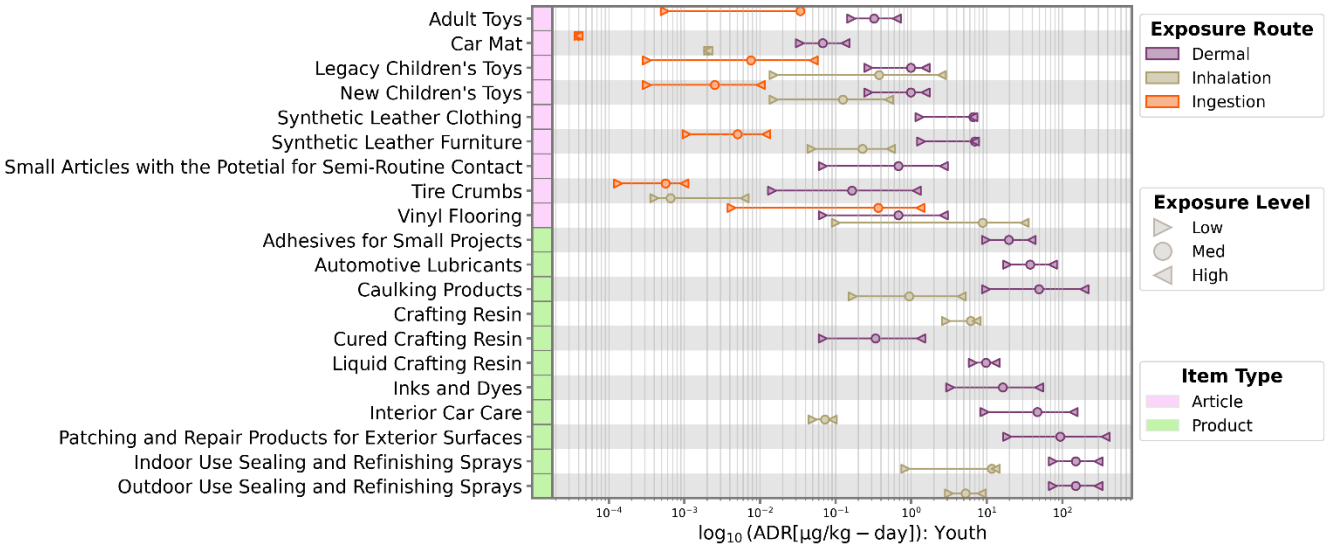


Figure 3-5. Acute Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Young Teens (11–15 Years) and Teenagers and Young Adults (16–20 Years)

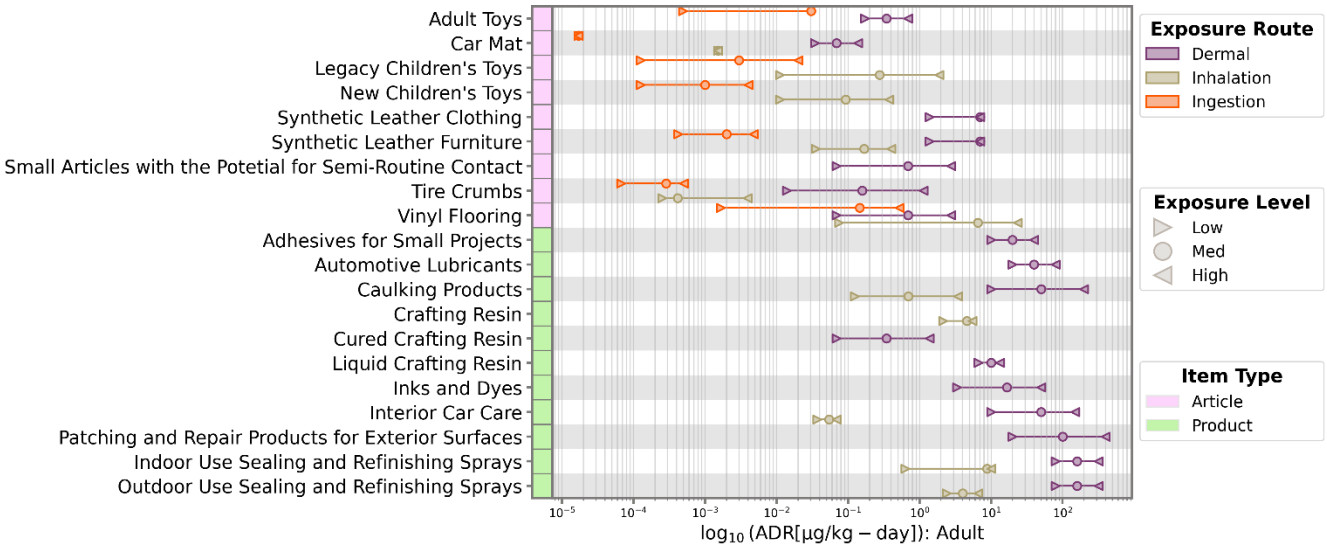


Figure 3-6. Acute Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Adults (21+ Years)

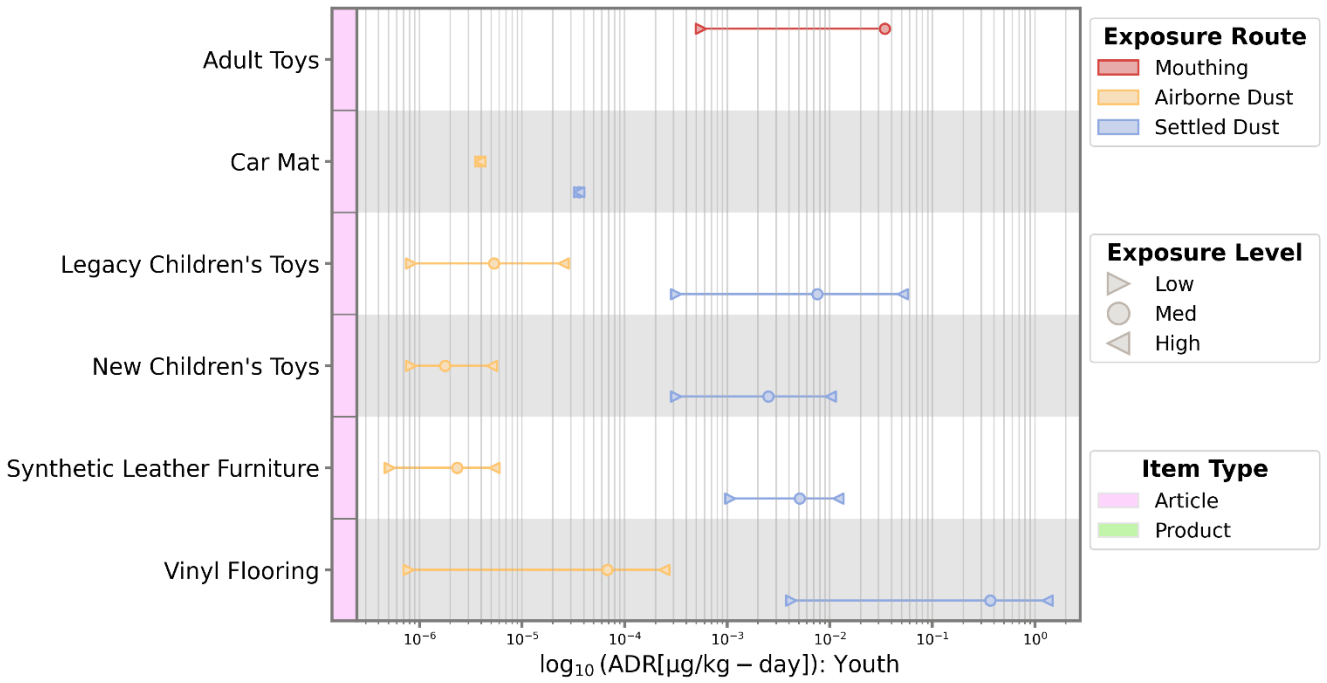


Figure 3-7. Acute Dose Rate of BBP from Suspended and Settled Dust Ingestion Exposure Routes for Young Teens (11–15 Years) and Teenagers and Young Adults (16–20 Years)

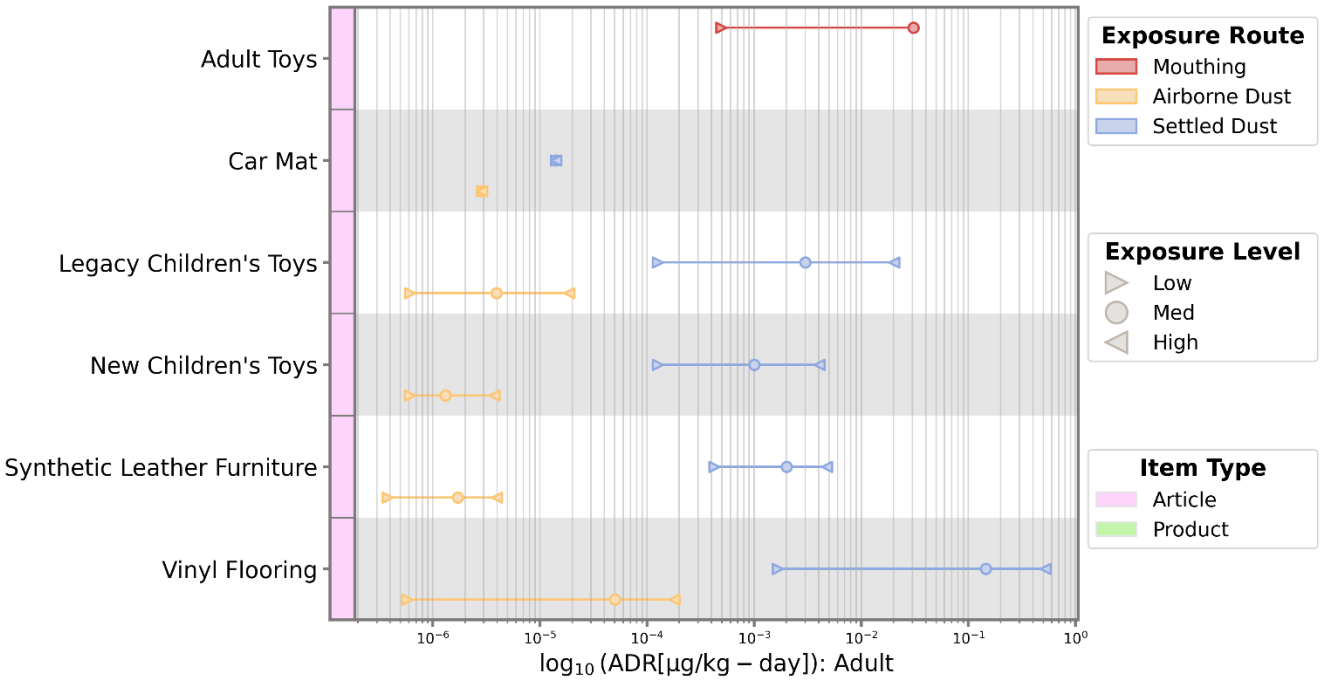


Figure 3-8. Acute Dose Rate of BBP from Suspended and Settled Dust Ingestion Exposure Routes for Adults (21+ Years)

3.2 Intermediate Average Daily Dose Conclusions and Data Patterns

The *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Risk Calculator* (U.S. EPA, 2025c) summarizes all the high-, medium-, and low-intensity use intermediate dose results from modeling in CEM and outside of CEM (dermal only) for all exposure routes and life stages. Only two product examples under the Adhesives and sealants COU and one product under the Paints and coatings COU were candidates 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 life stage for that exposure route.

Only caulking products, patching and repair products for exterior surfaces, and sealing and refinishing sprays (outdoor and indoor) 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. Infant to childhood life stages 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 life stages can use automotive and construction adhesives in home renovation projects or other hobbies. Infants to middle childhood life stages 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 3-9 to Figure 3-12 for intermediate dose visual representation. A noteworthy pattern is that bystander flooring adhesives inhalation doses for children younger than 10 years old are similar to dose values for users that are directly using or applying the product.

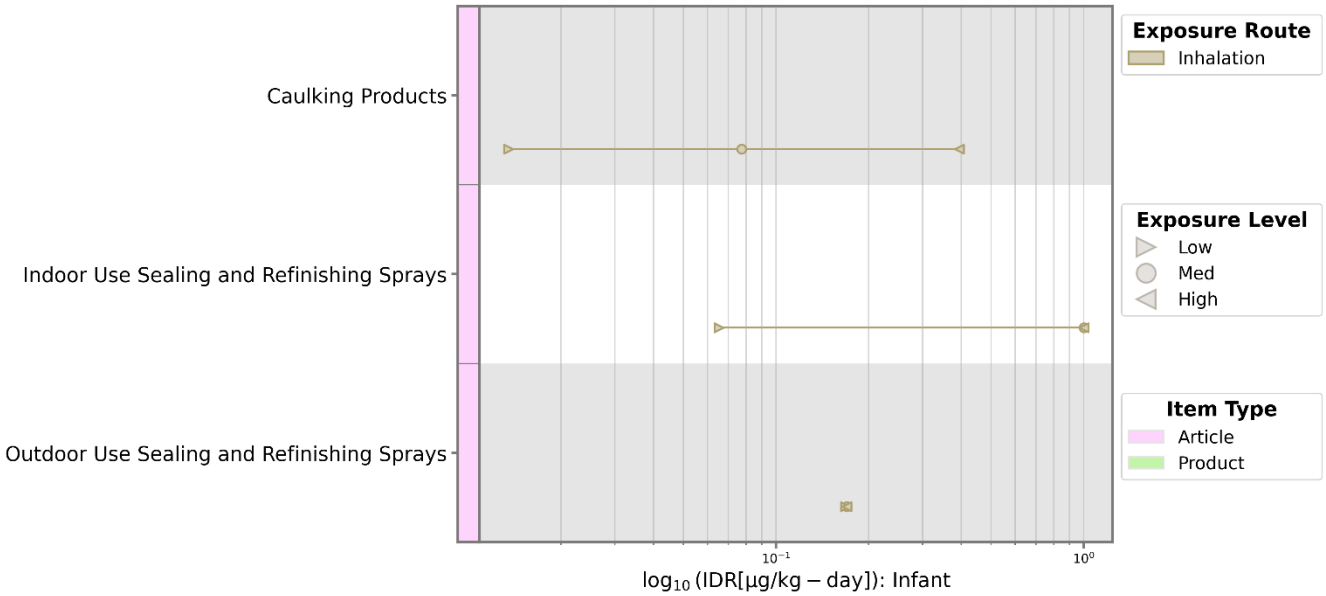


Figure 3-9. Intermediate Dose Rate for BBP from Inhalation Exposure Route for Infants (<1 Year) and Toddlers (1–2 Years)

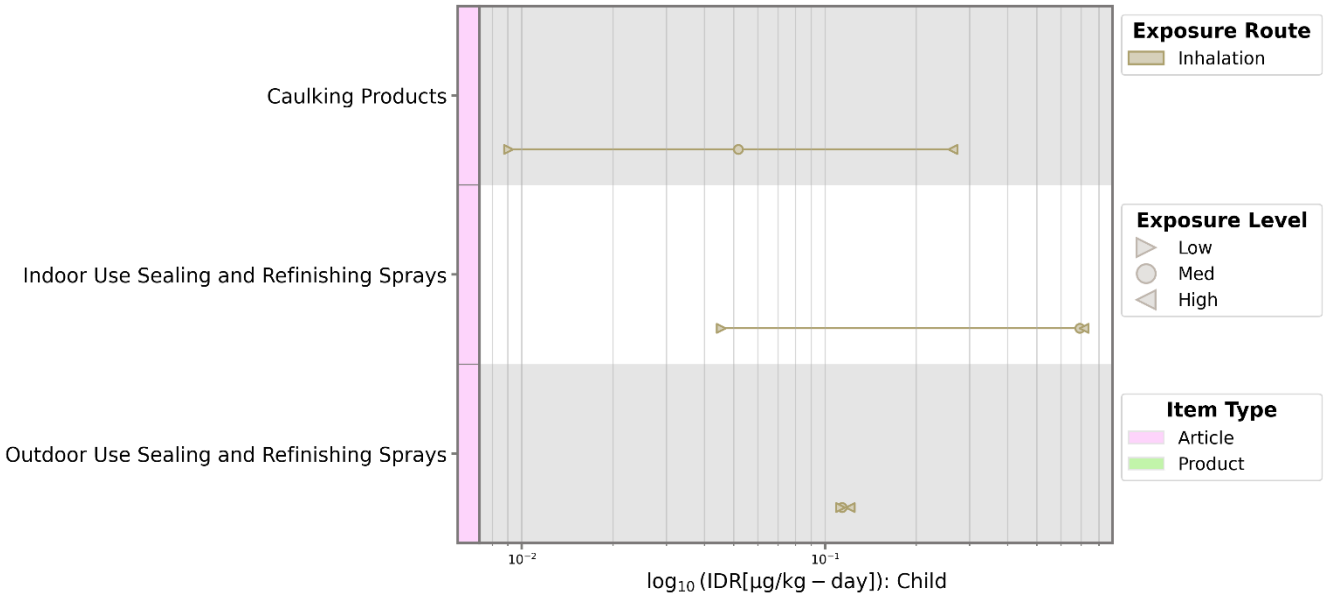


Figure 3-10. Intermediate Dose Rate for BBP from Inhalation Exposure Route for Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

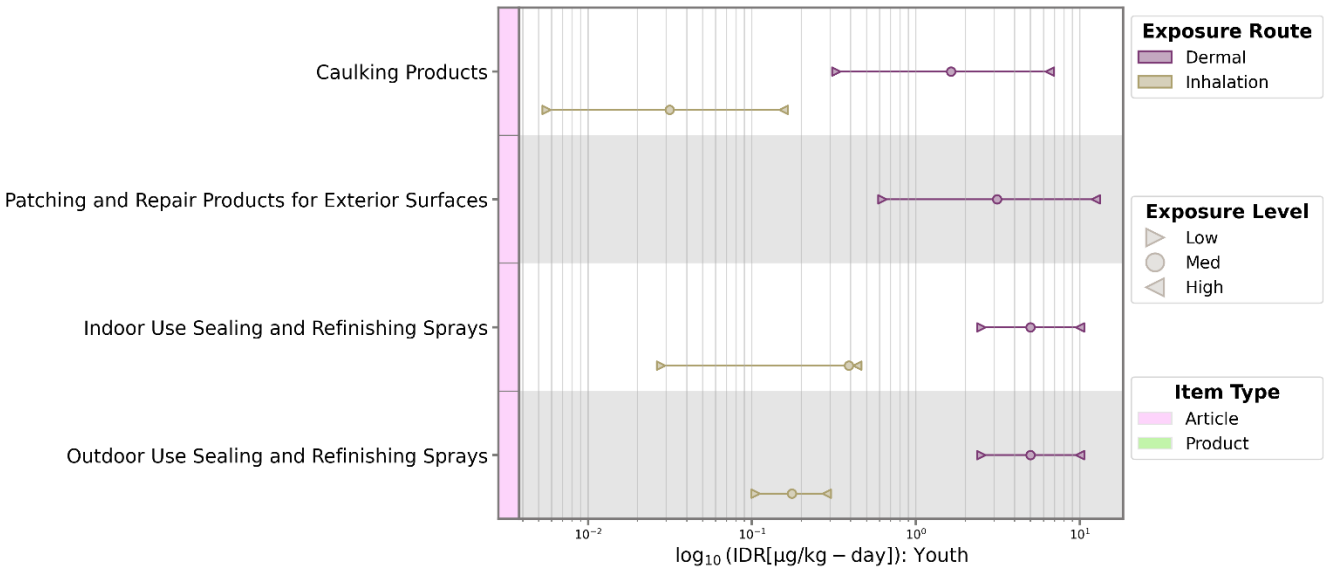


Figure 3-11. Intermediate Dose Rate of BBP from Inhalation and Dermal Exposure Routes for Young Teens (11–15 Years) and Teenagers and Young Adults (16–20 Years)

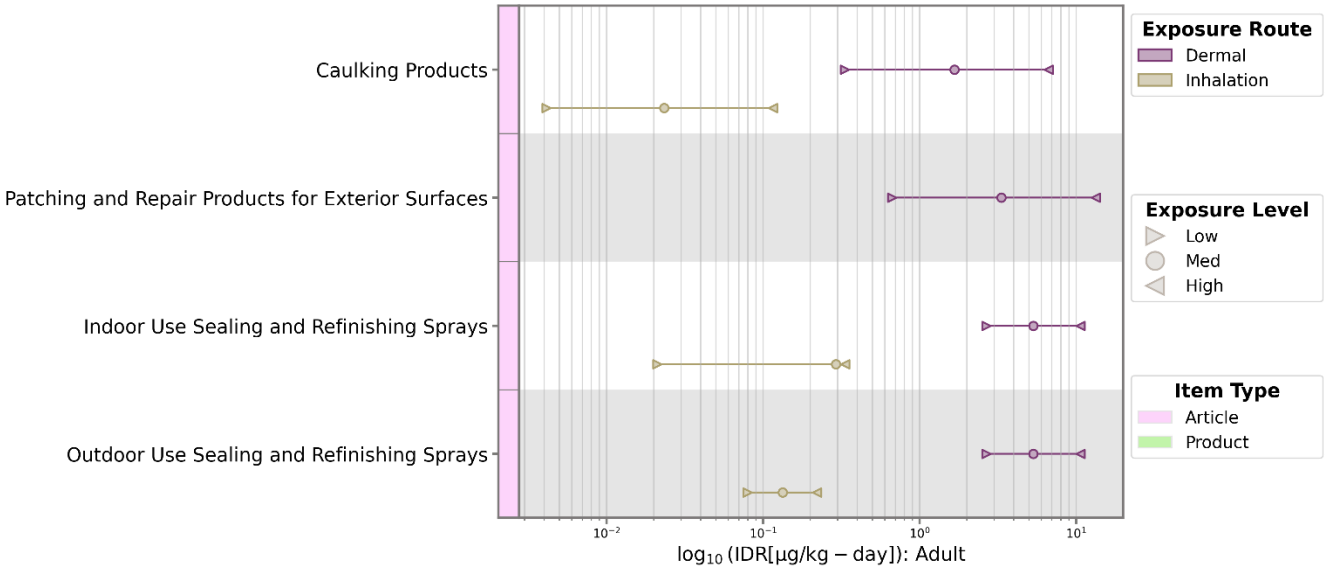


Figure 3-12. Intermediate Dose Rate of BBP from Inhalation and Dermal Exposure Routes for Adults (21+ Years)

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

The *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Risk Calculator* (U.S. EPA, 2025c) summarizes all the high-, medium-, and low-intensity use chronic daily dose results from modeling in CEM and outside of CEM (dermal only) for all exposure routes and all life stages. Some products and articles did not have dose results because the product or article was not targeted for that life stage or exposure route. Again, bystanders are people that are not in direct use or application of the product but can be exposed to BBP by proximity to the use of the product via inhalation of gas-phase emissions or suspended dust. Some product scenarios (*e.g.*, adhesives and sealants), 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 years). People older than 11 years can also be bystanders; however, the user scenarios utilize inputs that would result in larger exposure doses. The main purpose of the *Risk Evaluation for Butyl Benzyl Phthalate (BBP) - Supplemental Information File: Consumer Risk Calculator* (U.S. EPA, 2025c) is to summarize chronic daily dose results, show which products or articles did not have a quantitative result, and which results are used for bystanders. Data patterns are illustrated in figures in this section and includes summary descriptions of the patterns by exposure route and life stage. The following set of figures (Figure 3-13 to Figure 3-16) show chronic average daily dose data for all products and articles modeled in all life stages. For each life stage, figures are provided that show CADD estimated from exposure via inhalation, ingestion (aggregate of mouthing, suspended dust ingestion, and settled dust ingestion), and dermal contact.

The CADD figures resulted in similar overall data patterns as the acute doses with some differences driven by the chronic exposure durations. For example, dermal doses for all articles were generally higher than inhalation and ingestion doses, except for crafting resin, and vinyl flooring for which inhalation doses were higher. The higher inhalation doses for vinyl flooring and crafting resins are likely due to the larger surface area presence and weight fractions in comparison to other articles. For purposes of this risk evaluation, EPA assumed that the absorptive flux of BBP for solid and liquid products serves as an upper bound and assumes an excess of BBP in contact with the skin independent of concentration in the article. For this reason, products with similar use patterns and dermal skin contact inputs but differing BBP content have the same exposure dose results.

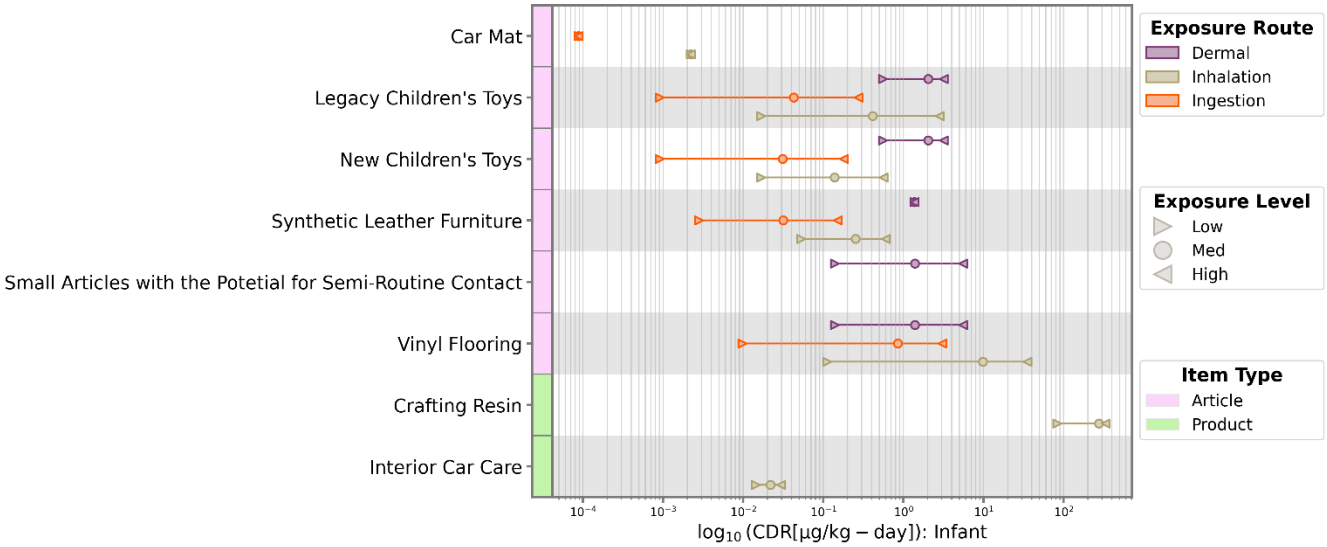


Figure 3-13. Chronic Dose Rate for BBP from Ingestion, Inhalation, Dermal Exposure Routes for Infants (<1 Year) and Toddlers (1–2 Years)

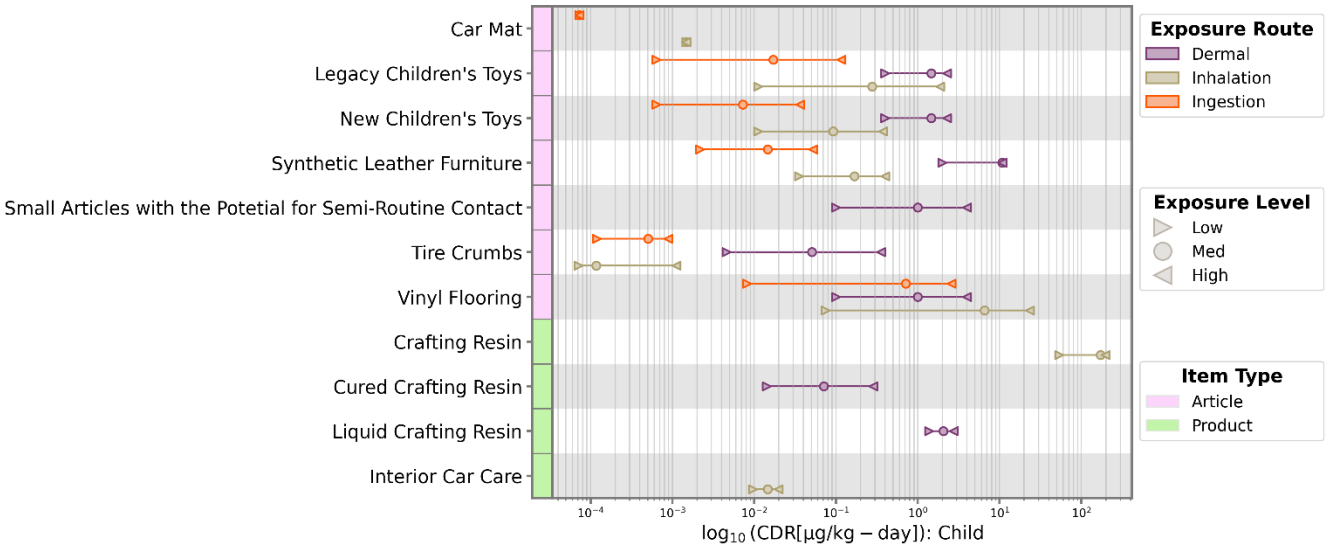


Figure 3-14. Chronic Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Preschoolers (3–5 Years) and Middle Childhood (6–10 Years)

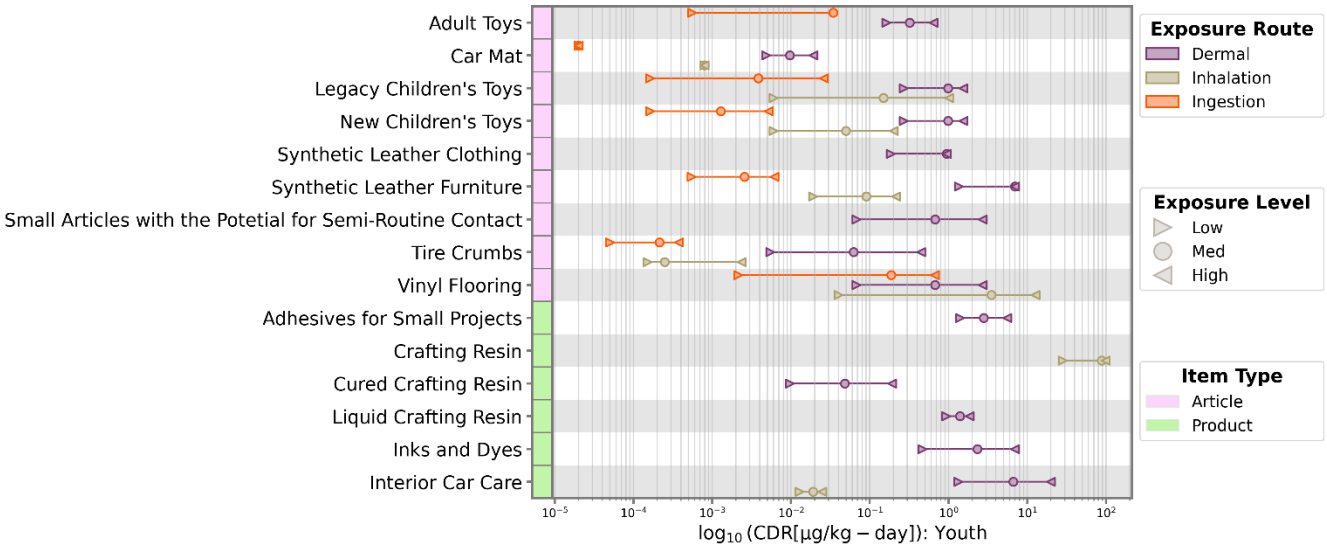


Figure 3-15. Chronic Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Young Teens (11–15 Years) and Teenagers and Young Adults (16–20 Years)

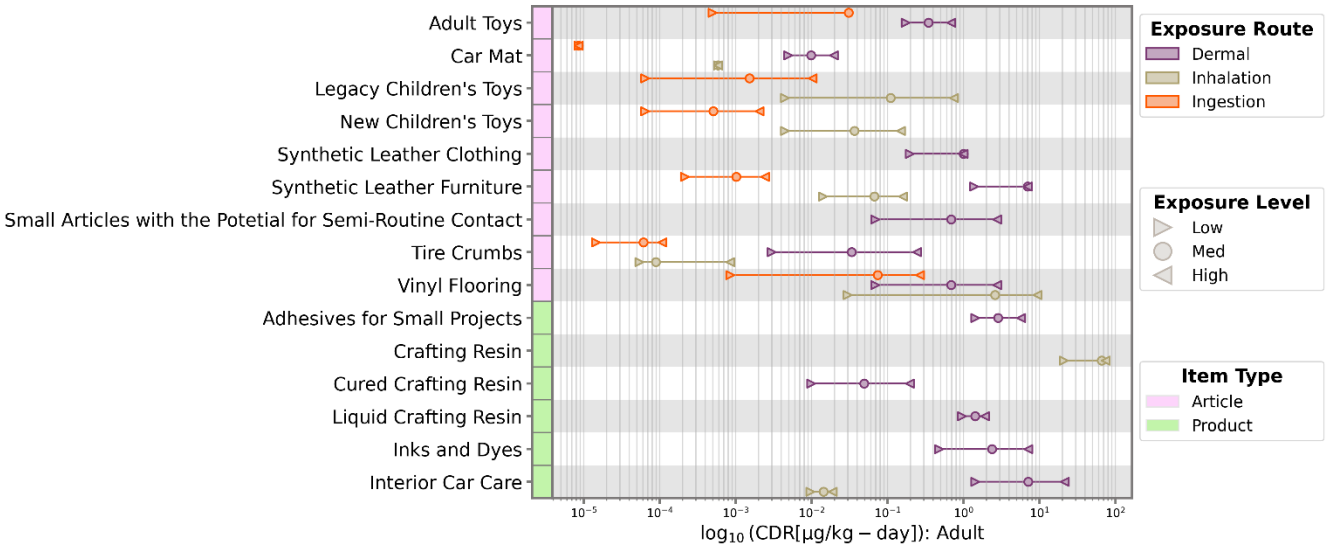


Figure 3-16. Chronic Dose Rate of BBP from Ingestion, Inhalation, and Dermal Exposure Routes for Adults (21+ Years)

4 INDOOR DUST MODELING and MONITORING COMPARISON

In this indoor exposure assessment, EPA compared modeling and monitoring data. Modeling data used in indoor dust assessment originated from the consumer exposure assessment (Section 2) to (1) reconstruct major indoor sources of BBP into dust, and (2) obtain COU- and product-specific exposure estimates for ingestion and inhalation of dust. Exposure to BBP via ingestion of dust was assessed for all articles expected to contribute significantly to dust concentrations due to high surface area (greater than ≈1 m^2) for either a single article or collection of similar articles as appropriate. These included the following:

- indoor synthetic leather furniture,
- vinyl flooring,
- carpet tiles,
- car mats, and
- children's toys, both legacy and new.

These exposure scenarios were modeled in CEM for inhalation, ingestion of suspended dust, and ingestion of dust from surfaces. See Section 2.2.3.1 for CEM parameterization, input values, and article-specific scenario assumptions and sources as well as the *BBP Consumer Risk Calculator* (U.S. EPA, 2025c), which summarizes ingestion of settled dust doses used in this comparison.

The monitoring data considered are from residential dust samples from U.S.-based studies. Other non-residential environments can have these articles such as daycares, offices, malls, schools, car interiors, and other public indoor spaces. The indoor consumer articles exposure scenarios were modeled with stay-at-home parameters that consider use patterns similar to or higher than those in other indoor environments. Therefore, EPA concludes that exposures to similar articles in other indoor environments are included in the residential assessment as a health-protective, upper-bound scenario. The monitoring data considered are from residential dust samples from U.S.-based studies. EPA used eight U.S. monitoring studies to generate an estimate of overall BBP exposure from ingestion of indoor dust and performed a monitoring and modelling comparison. The monitoring studies and assumptions made to estimate exposure are described in Section 4.1.

4.1 Indoor Dust Monitoring Data

During systematic review, a total of 89 studies containing potential indoor dust monitoring data for BBP were identified including data from the Unites States, Asian, European, and other countries. Out of the 89 studies, 11 collected original data, were conducted in the United States, reported high-quality sampling and analytical methods, and measured dust in homes, offices, or other indoor environments that are representative of the U.S. general population. Of the 11 studies, 8 were selected because they collected settled indoor dust (see Table 4-1). Of these eight studies, only four reported the statistical summaries needed for this analysis, settled dust average, and 95th percentile measured concentrations, which are used in the comparison to indoor dust ingestion modeling data (Section 4.3).

In Wilson et al. (2001), 10 settled dust samples were collected from U.S. child daycare centers. Five private daycares, 4 Head Start (federally funded daycare centers), and 1 back-up center participated. All had at least one classroom with preschool children ages 3 to 5 years. Three centers were in rural communities and six in urban centers. Classroom floor dust was collected in the area where the children played the most.

In Wilson et al. (2003), four settled dust samples from U.S. child daycare centers and nine samples from children's homes were collected. In addition, nine hand wipe samples were taken from children at the

daycares. Classroom and house floor dust were collected in the areas indicated by the teacher or parent as being where the children played most often. For hand wipe samples, each child's samples were collected by the child's caregiver. Two wipes for each child were collected at the daycare center, one just before lunch and before washing the child's hands, on each of the two sampling days. Two additional wipes were collected at home, just before dinner and before washing the child's hands, on both sampling days.

In Rudel et al. (2001), six settled dust samples were collected from the Unites States. One sample was from an office and five were from three different homes in the living areas, attic, and basement. The study does not report the year of the samples taken. Sample collection was taken 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. Collection occurred 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 approximately 30 minutes.

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

In Bi et al. (2018), 92 settled dust samples were collected from homes in Texas during 2014 and 2015. Dust sampling was conducted mainly in children's rooms. Dust was collected from the floor surface and from objects within 30 cm above the floor.

In Hammel et al. (2019), 188 settled dust samples were collected from the living room and playroom of homes in North Carolina during 2014 to 2016. Families were instructed not to clean their homes, specifically mop or vacuum, for at least 2 days prior to the scheduled visit. For collection, the entire exposed floor area of the room in which the child spent the most time active and awake, typically a living room or playroom, was vacuumed. A total of 202 hand wipe samples were also collected. Families were instructed not to wash their child's hands for at least 1 hour prior to the home visit. During the visit, research staff collected a hand wipe sample from each child using pre-cleaned cotton twill wipes.

Table 4-1 reports summary statistics for BBP content in dust from indoor environments. EPA compiled data from multiple indoor environments such as homes, retail, offices, daycares, and gyms. The studies reported various indoor environments the results statistics combined and by environment (see Table 4-1). Statistics (*e.g.*, mean, median, etc.) were directly taken from each study, and when individual data were provided, EPA calculated the summary statistics. Sampling methods that use wipes and vacuums to collect samples from surfaces are categorized as settled dust and were used in the assessment of dust ingestion route in the monitoring indoor dust exposure assessment. Combined indoor environments mean and medians tend to be higher than individual environments. BBP measurements from the study are provided in Table 4-1.

Table 4-1. Detection and Quantification of BBP in House Dust from Various 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 (%)
Wilson et al. (2001) [b]	Daycare center	10	67.7	NR	15.1	175	NR	NR	NR
Wilson et al. (2003)	Home	9	5.86	NR	0.496	15.6	NR	NR	NR
	Daycare center	4	3.72	NR	0.022	7.43	NR	NR	NR
	Hand wipe (at daycare) [c]	9	306	NR	<0.500	1325	NR	NR	33
	Hand wipe (at home) [c]	9	297	NR	<0.500	938	NR	NR	22
Rudel et al. (2001)	Combined	6	117	NR	12.1	524	184	NR	100
Guo and Kannan (2011)	Home	33	NR	21.1	3.6	393	NR	NR	100
Dodson et al. (2015)	Home	49	NR	19	NR	330	NR	220 [g]	98
Bi et al. (2015) [d]	Combined	43	494	93	5.7	5,224	1,017	NR	100
	Apartment	7	146 [f]	68	5.7	525	198	NR	100
	Home	10	94 [f]	29	8	619	187	NR	100
	Home garage	3	36	36	12	55	34	NR	100
	Student dormitory	5	424	1170	95	3,814	1,529	NR	100
	Gym	3	164	158	37	297	130	NR	100
	Office	7	1,262	500	93	5,224	1,812	NR	100
	Commercial stores	4	555	44	15	2,118	1,042	NR	100
	Daycare center	5	359	167	29	1,134	455	NR	100
Bi et al. (2018)	Home	92	128 [f]	20.1	<MDL	2,380	383	NR	80
Hammel et al. (2019) [e]	Home	188	NR	13.681	ND	NR	NR	132.508 [g]	99

MDL = method detection limit; ND = non-detect; NR = not reported
[a] Combined refers to multiple indoor environments including household living areas, attic, basement, and an office building
[b] Reported as ppm.
[c] Reported as ng/wipe.
[d] Reported as mg/kg.
[e] Reported as ng/g.
[f] Used in mean ingestion weighted average concentration calculation (Equation 4-1).
[g] Used in 95th percentile ingestion weighted average concentration calculation (Equation 4-1).

The number of studies sampled, states, and samples among the studies provide a robust level of confidence in these data adequately representing the U.S. population. Additionally, the study with the largest number of samples, Hammel et al. (2019), provided generic descriptions of the articles that may be sources of BBP in the indoor environment sampled. A comparison between modeled and monitoring data can provide some insight into the distribution and variability within monitoring and modeling estimates. However, it is noteworthy that the monitoring data are an aggregate of all indoor TSCA and non-TSCA sources of BBP in dust and a comparison with only TSCA sources modeling results can be challenging to characterize.

4.2 Indoor Dust Monitoring Approach and Results

To estimate BBP dust ingestion, the central tendency, ingestion-weighted average dose is first calculated

from the reported means and medians of measured concentrations for residential samples (homes and apartments) in Table 4-1 (see table note "a"). Because studies that did not report means were not used in the calculation, only residential settled dust concentration values were used to compare to modeling results (Section 4.3). The same equation was used to calculate the high-end value using the reported maximums and 95th percentile. The central tendency, ingestion-weighted average concentration is calculated using Equation 4-1.

Equation 4-1. Ingestion-Weighted Average Concentration Calculation

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

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

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

BBP dust ingestion was calculated according to Equation 4-2 for two scenarios: central tendency, which was the geometric mean (GM) dust ingestion and median BBP concentration in dust. The high-end tendency was the dust ingestion 95th percentile BBP concentration in dust.

Equation 4-2. Calculation of BBP Settled Dust Ingestion Dose

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

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

Age Range		0 to <1 Month	1 to <3 Months	3 to <6 Months	6 Months to <1 Year	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 to <16 Years	16 to 21 Years
Dust ingestion (mg/day) [a]	Geometric mean	19	21	23	26	23	14	15	13	8.8	3.5
	95th Percentile	103	116	112	133	119	83	94	87	78	46
Body weight (kg) [b]		4.8	5.9	7.4	9.2	11.4	13.8	18.6	31.8	56.8	71.6
BBP ingestion (µg/kg-day)	Central tendency (46 µg BBP/g dust)	1.8E−1	1.7E−1	1.4E−1	1.3E−1	9.4E−2	4.7E−2	3.7E−2	1.9E−2	7.2E−3	2.3E−3
	High end (151 µg BBP/g dust)	3.2	3.0	2.3	2.2	1.6	9.1E−1	7.6E−1	4.1E−1	2.1E−1	9.7E−2

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

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

Age Range		21 to <30 Years	30 to <40 Years	40 to <50 Years	50 to <60 Years	60 to <70 Years	70 to <80 Years	>80 Years
Dust ingestion (mg/day) [a]	Geometric mean	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	95th Percentile	46	46	46	46	46	46	46
Body weight (kg) [b]		78.4	80.8	83.6	83.4	82.6	76.4	68.5
BBP ingestion (µg/kg-day)	Central tendency (46 µg BBP/g dust)	2.1E−3	2.0E−3	1.9E−3	1.9E−3	2.0E−3	2.1E−3	2.4E−3
	High-end (151 µg BBP/g dust)	8.8E−2	8.6E−2	8.3E−2	8.3E−2	8.4E−2	9.1E−2	1.0E−1

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

4.3 Indoor Dust Comparison Between Monitoring and Modeling Ingestion Exposure Estimates

The exposure dose estimates for indoor dust from the CEM Model are larger than those indicated by the monitoring approach. Table 4-4 compares the sum of the chronic dose central tendency for indoor dust ingestion from CEM outputs for all COUs to the central tendency-predicted daily dose from the monitoring approach. EPA only considered modeling TSCA COU related articles that are present in residences and homes for comparison with monitoring data. Car mats are present in indoor environments like vehicles but are not used in homes and therefore inclusion would not be appropriate.

Table 4-4. Comparison Between Modeled and Monitored Daily Dust Intake Estimates for BBP

Life Stage	Daily BBP Intake Estimate from Dust (µg/kg-day) Modeled Exposure [a]	Daily BBP Intake Estimate from Dust (µg/kg-day) Monitoring Exposure [b]	Margin of Error (Modeled ÷ Monitoring)
Infant (<1 year)	7.9E–1	1.6E–1[c]	5
Toddler (1–2 years)	9.8E–1	9.4E–2	10
Preschooler (3–5 years)	1.1	4.2E–2	26
Middle childhood (6–10 years)	3.9E–1	1.9E–2	20
Young teen (11–15 years)	2.2E–1	7.2E–3	30
Teenager (16–20 years)	1.7E–1	2.3E–3	76
Adult (21+ years)	7.7E–2	2.1E–3 [d]	37

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

The sum of BBP intakes from dust in CEM-modeled scenarios were considerably higher than those predicted by the monitoring approach (see Table 4-4). These discrepancies partially stem from differences in the exposure assumptions of the CEM vs. the assumptions made when estimating daily dust intakes in Özkaynak et al. (2022). Dust intake noted in Özkaynak et al. (2022) declines rapidly as a person ages due to behavioral factors including walking upright instead of crawling, cessation of exploratory mouthing behavior, and a decline in hand-to-mouth events. This age-mediated decline in dust intake, which is more rapid for the Özkaynak et al. (2022) study than in CEM, partially explains why the margin of error between the modeled and monitoring results grows larger with age. Another explanation is the assumption that the sum of the indoor dust sources in the CEM-modeled scenario is representative of items found in typical indoor residences. It is likely that individual residences have varying assortments and amounts of the products and articles that are sources of BBP, resulting in lower and higher exposures. The modeling scenario with the largest relative contribution (99%) to the total modeling aggregate is vinyl flooring, which might be using a larger surface area presence than in U.S. homes in the monitoring studies used in the comparison. Synthetic leather furniture and children's toys, both legacy and new, have lower margin of error values than the monitoring dose estimated; see the *Butyl Benzyl Phthalate (BBP) Consumer Risk Calculator* (U.S. EPA, 2025c). In addition, the monitoring data are an aggregate of all indoor TSCA and non-TSCA sources of BBP in dust and a comparison with only TSCA sources modeling results can be challenging to compare.

In the indoor dust modeling assessment, EPA reconstructed the scenario using consumer articles as the source of BBP in dust. CEM modeling parameters and inputs for dust ingestion can partially explain the

differences between modeling and monitoring estimates. For example, surface area, indoor environment volume, and ingestion rates by life stage were selected to represent common use patterns. CEM calculates BBP concentration in both small particles (respirable particles) and large particles (dust) that settled on the floor or surfaces. The model assumes that particles bound to BBP are available via incidental dust ingestion. It also estimates exposure based on a daily dust ingestion rate and a fraction of the day that is spent in the zone with the BBP-containing dust. The use of a weighted dust concentration can also introduce discrepancies between monitoring and modeling results. Additionally, the scenario that is mainly driving the large difference is vinyl flooring, which may overestimate surface area presence in indoor environments.

5 WEIGHT OF SCIENTIFIC EVIDENCE

5.1 Consumer Exposure Analysis Weight of Scientific Evidence

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

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

In general, designation of robust confidence suggests a thorough understanding of the scientific evidence and uncertainties. The supporting weight of scientific evidence outweighs the uncertainties to the point where it is unlikely that the uncertainties could have a significant effect on the exposure estimate. The designation of moderate confidence suggests some understanding of the scientific evidence and uncertainties. More specifically, the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure estimates. The designation of slight confidence is assigned when the weight of scientific evidence may not be adequate to characterize the scenario, and when there is an absence of complete information and there are additional uncertainties that may need to be considered. The designation of slight to moderate confidence suggests that some aspects of the analysis are reasonably adequate but other aspects are not adequate or well understood to characterize the exposure.

Table 5-1 summarizes the overall uncertainty per COU, and a discussion of rationale used to assign the overall uncertainty. The subsections preceding 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 emphasize protective assumptions that are not considered outliers, excessive, or unreasonable.

Product Formulation and Composition

Variability in the formulation of consumer products—including changes in ingredients, concentrations, and chemical forms—can introduce uncertainty in exposure assessments. In addition, data were sometimes limited for weight fractions of BBP in consumer goods. EPA obtained BBP weight fractions in various products and articles from MSDS, 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. The screening assessment for dermal exposure largely did not depend on weight fractions as a modeling input. Instead, it was highly dependent on the BBP experimental dermal load applied from literature for liquid products and solid articles. 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 one or multiple sources but insufficient description on how the concentrations were obtained. *Robust* for products/articles with one or more (preferrable) than one source with sufficient description on how the concentrations were obtained, 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 such as frequency of use, duration of use, methods of application, and skin contact area 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. There is *robust* overall confidence for most product use patterns.

Article Use Patterns

For inhalation and ingestion exposures to articles, the high-, medium-, and low-intensity use scenario default values from CEM 3.2's prepopulated scenarios were selected for indoor use environment/room volume, interzone ventilation, and surface layer thickness. For dermal exposures, article use patterns such as frequency of use and skin contact area are expected to have a range of low- to high-use intensities. For articles that do not use duration of use as an input in CEM, professional judgment was used to select the duration of use/article contact duration for the low-, medium-, and high-exposure scenario levels for most articles except for carpet tiles and vinyl flooring. Carpet tiles and vinyl flooring contact duration values were taken from EPA's Standard Operating Procedures for Residential Pesticide Exposure Assessment for the high exposure level (2 hours; time spent on floor surfaces) (U.S. EPA, 2012). ConsExpo (U.S. EPA, 2012) for the medium exposure level (1 hour; time a child spends crawling on treated floors), and professional judgment for the low exposure level (0.5 hour). There are more uncertainties in the assumptions and professional judgment for contact duration inputs for articles, and hence EPA has *moderate* confidence in those inputs.

Article Surface Area

The surface area of an article directly affects the potential for BBP emissions to the environment. For each article modeled for inhalation exposure, low, medium, and high estimates for surface area were calculated (Section 2.1). This approach relied on manufacturer-provided dimensions where possible, or values from the EPA *Exposure Factors Handbook* for floor and wall coverings. For small items that might be expected to be present in a home in significant quantities, such as children's toys, aggregate values were calculated for the cumulative surface area for each type of article in the indoor environment. Overall confidence in surface area is *robust* for articles like furniture, wall coverings, flooring, and toys because there is a good understanding of the presence and dimensions of these articles in indoor environments.

Human Behavior
CEM 3.2 has three different activity patterns: stay-at-home; part-time out-of-the home (daycare, school, or work); and full-time, out-of-the-home. The activity patterns were developed based on the CHAD. 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) aged 1 month to 5 years of age for 15 minutes per session across 20 sessions (Smith and Norris, 2003). There was considerable variability in the data due to behavioral differences among children of the same life stage. For instance, while children aged 6 to 9 months had the highest average mouthing duration for toys at 39 minutes per day, the minimum duration was 0 minutes while 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 (excluding 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 BBP. EPA assigned a *moderate* confidence associated with the duration of activity for mouthing because the magnitude of the overestimation is not well characterized. Because all other human behavior parameters are well understood, or the ranges used capture use patterns representative of various life stages, the overall confidence in use patterns is *robust*.

Inhalation and Ingestion Modeling Tool
Confidence in the model used considers whether the model has been peer reviewed and whether it was applied in a manner appropriate to its design and objective. For example, the model used (CEM 3.2) has been peer reviewed (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 of BBP Exposure for Liquids and Solids
Experimental dermal data was identified via the systematic review process to characterize consumer dermal exposures to liquids or mixtures and formulations and solid articles containing BBP (see Sections 2.3.2 and 2.3.3). The confidence in the dermal exposure to liquid and solid products and articles model used in this assessment is *moderate*.

EPA identified only four sets of experimental data related to the dermal absorption of BBP, Elsisi (1989), Dupont (2006b), Dupont (2006a), and Sugino (2017). The Dupont (2006b) and Dupont (2006a) studies were selected for this assessment because they are more recent in comparison to Elsisi (1989) and use human skin in comparison to Elsisi (1989) and Sugino (2017), which used *in vivo* rat skin. The two Dupont studies also considered formulations and an experimental setup that included detailed temperature and humidity controls, rather than a neat chemical study, which may have overestimated BBP exposure results.

A source of uncertainty regarding the dermal absorption of BBP from products or formulations stems from the varying concentrations and co-formulants that exist in products or formulations containing BBP. For purpose of this risk evaluation, EPA assumed that the absorptive flux of BBP formulations measured from *in vitro* human experiments served 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 solid articles. Dermal contact with products or formulations that have lower concentrations of BBP may exhibit lower rates of flux since there is less material available for absorption. Conversely, co-formulants or materials within the products or formulations might lead to enhanced dermal absorption—even at lower concentrations, but the magnitude of enhanced dermal absorption is not clear. Therefore, it is uncertain whether the products or formulations containing BBP would result in decreased or increased dermal absorption.

Ingestion via Mouthing

EPA did not identify BBP chemical migration rates to saliva with a correlation to weight fractions of BBP similar to those used in this assessment. A theoretical framework based on physical and chemical properties of BBP, and the solid matrix material was used to estimate chemical migration rates. This model was internally and externally validated against measured diffusion coefficients and shown to have good predictive capability for chemicals with molecular weights between 30 and 1,178 g/mol at temperatures ranging from 4 to 180 °C (Aurisano et al., 2022), which are well within BBP properties and temperatures during product use. Major limitations of the chemical migration rate estimate calculation approach are that there (1) is no understanding of the correlation between concentration of BBP in consumer products and the calculated chemical rate, and (2) are no available data to compare the estimated chemical rate value. These limitations result in a significant level of uncertainty for the estimated chemical migration rate, as the value may also differ among similar items due to variations in chemical makeup and polymer structure. Thus, it is unclear whether the migration rate value is applicable to consumer goods with low weight fractions of BBP. EPA has a *slight to moderate* confidence in the chemical migration rate value in the context of this assessment consumer product considerations and a *slight to moderate* confidence in the overall modeling approach.

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

Consumer COU Category; Subcategory	Weight of Scientific Evidence	Overall Confidence
Construction, paint, electrical, and metal products; Adhesives and sealants	Three 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 projects (2), caulking products (5), and patching and repair products for exterior repairs (5). Of these three scenarios, adhesives for small projects and patching and repair products for exterior repairs were assessed for dermal exposures only because inhalation and ingestion would have low exposure potential. The overall confidence in this COU's inhalation exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. For dermal exposure, EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of adhesives was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Inhalation– Robust Dermal – Moderate
Construction, paint, electrical, and metal products; Paints and coatings	Three 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): touch up auto paint (2), sealing and refinishing sprays (indoor use) (2), and sealing and refinishing sprays (outdoor use) (1). Of these three scenarios, touch up auto paint was not quantitatively assessed because appropriate use of the product avoids dermal contact and due to the small amount used per event inhalation, and ingestion exposures are expected to be smaller than the other examples in this COU. The sealing and refinishing sprays indoor and outdoor scenarios were assessed for dermal and inhalation due to the potential large area usage and spray application would facilitate volatilization of the product for inhalation. The overall confidence in this COU's inhalation exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of paints and coatings was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Inhalation– Robust Dermal – Moderate
Furnishing, cleaning, treatment/care products; Fabrics, textiles, and leather products	Two different scenarios were assessed under this COU for two article types with differing use patterns for which each scenario had also multiple identified article examples (in parenthesis): synthetic leather furniture (2), and synthetic leather clothing (>6). The synthetic leather furniture scenario was part of the indoor assessment and evaluated for all exposure routes. Clothing was assessed for dermal exposures only due to the very low concentration of BBP and limited use from the reported items or similar items, inhalation and ingestion is not expected to be significant. The overall confidence in this COU's inhalation and dust ingestion exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. The mouthing parameters used such as duration and surface area for infants to children are very well understood, while older groups have less specific information because mouthing behavior is not expected. The chemical migration value is	Inhalation, and Dust Ingestion– Robust Mouthing – Slight to moderate Dermal – Moderate

Consumer COU Category; Subcategory	Weight of Scientific Evidence	Overall Confidence
	BBP-specific, and the main source of uncertainty are related to article formulation and chemical migration dynamics may not be very well characterized. Specifically, it is unclear whether the migration rate values are applicable to consumer goods with low (<15%) weight fractions of BBP. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of synthetic leather textiles was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	
Furnishing, cleaning, treatment/care products; Floor coverings; construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles fabrics, textiles, and apparel	One scenario was assessed under this COU for one article type: vinyl flooring. This scenario was part of the indoor assessment and evaluated for all exposure routes except mothing. The overall confidence in this COU's inhalation and dust ingestion exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of vinyl flooring was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Inhalation, and Dust Ingestion– Robust Dermal – Moderate
Other uses; Automotive products, fluids	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): automotive lubricants (2), and interior car care (1). Of these two scenarios, automotive lubricants were assessed for dermal exposures only because inhalation and ingestion would have low exposure potential. Interior car care product was assessed for dermal and inhalation because the spray application promotes volatilization of the product and inhalation. The overall confidence in this COU's inhalation exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of fluid automotive products was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters, such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Inhalation– Robust Dermal – Moderate
Other uses; Automotive articles	One scenario was assessed under this COU for one article type: car mats. This scenario was part of the indoor assessment and evaluated for all exposure routes except mothing. The overall confidence in this COU's inhalation and dust ingestion exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of car mats was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of	Inhalation, and Dust Ingestion– Robust Dermal – Moderate

Consumer COU Category; Subcategory	Weight of Scientific Evidence	Overall Confidence
	use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	
Other uses; Novelty articles	One scenario was assessed under this COU for one article type: adult toys. This scenario was assessed for dermal and mouthing. More than one article input parameter captures the variability in product use represented in the high, medium, and low intensity use estimates, such as mouthing surface area and dermal contact frequency. The overall confidence in this COU dermal and mouthing exposure estimate is moderate. The mouthing parameters used such as duration and surface area for infants to children are very well understood, while older groups have less specific information because mouthing behavior is not expected; therefore, EPA made some assumptions for adult mouthing surface are based on available measurements. The Agency has moderate confidence that the assumptions were based of reliable adult mouth surface area, but some uncertainties remain on mouthing behavior, duration, and frequency for this COU article examples, adult toys. The chemical migration value is BBP specific, and the main source of uncertainty are related to article formulation and chemical migration dynamics may not be very well characterized. Specifically, it is unclear whether the migration rate values are applicable to consumer goods with low (<15%) weight fractions of BBP. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of adult toys was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. However Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Dermal – Moderate Mouthing – Slight to moderate
Packaging, paper, plastic, hobby products; Ink, toner, and colorant products	One scenario was assessed under this COU for one product type with varying number of identified product examples (in parenthesis): Inks and dyes (2). This scenario was assessed for dermal exposure only because inhalation and ingestion would have low exposure potential. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of inks and dyes was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters, such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Dermal – Moderate
Packaging, paper, plastic, hobby products; Toys, playground, and sporting equipment	Three different scenarios were assessed under this COU for various articles with differing use patterns: legacy children's toys, new children's toys, and tire crumb. Toys scenarios were included in the indoor assessment for all exposure routes, inhalation, dust ingestion, mouthing, and dermal with varying use patterns and inputs. Tire crumb was also part of the indoor assessment for all exposure routes except mouthing. The overall confidence in this COU's inhalation and dust ingestion exposure estimate is robust because the CEM default parameters represent actual use patterns and location of use. See Section 2.1.2 for number of products, product examples, and weight fraction data. The overall confidence in this COU mouthing and dermal exposure assessment is moderate. The mouthing parameters used such as duration and surface area for infants to children are very well understood, while older groups have less specific information because mouthing behavior is not expected. The chemical migration value is BBP-specific, and the main source of uncertainty are related to article formulation and chemical migration dynamics may not be very well characterized. Specifically, it is unclear whether the migration rate values are applicable to consumer goods with low (<15%) weight fractions of BBP.	Inhalation and Dust Ingestion – Robust Dermal – Moderate Mouthing – Slight to moderate

Consumer COU Category; Subcategory	Weight of Scientific Evidence	Overall Confidence
	For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of toys and tire crumb was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters, such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	
Packaging, paper, plastic, hobby products; Packaging (excluding food packaging) and other articles with routine direct contact during normal use, including rubber articles; plastic articles (hard); plastic articles (soft)	One scenario was assessed under this COU for a collective of small articles with potential for semi-routine contact, such as packaging, including plastic bags and pouches, vinyl shelf liner, bottom surface of shoe, small exterior clothing components, disposable gloves. This scenario was assessed for dermal exposure only because inhalation and ingestion would have low exposure potential. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of these articles was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Dermal – Moderate
Packaging, paper, plastic, hobby products; Arts, crafts, and hobby materials	One scenario was assessed under this COU for a collective of small articles with potential for semi-routine contact, such as modeling clay, jewelry making crafts. This scenario was assessed for dermal exposure only because inhalation and ingestion would have low exposure potential. For dermal exposure EPA used a dermal flux approach, which was estimated based on BBP *in vitro* dermal absorption in humans. An overall moderate confidence in dermal assessment of these articles was assigned. Uncertainties about the effect formulations have in overall absorption increase uncertainty. Other parameters, such as frequency and duration of use, and surface area in contact, are well understood and representative, resulting in a moderate overall confidence.	Dermal – Moderate

5.2 Indoor Dust Monitoring Weight of Scientific Evidence

The weight of scientific evidence for the indoor dust exposure assessment of BBP (Table 5-2**)** is dependent on studies that include indoor residential dust monitoring data (Table 4-4). Studies included indoor dust samples taken from residences and multiple indoor environments were extracted. In the case of BBP, nine studies collected settled indoor dust. Seven studies contained data on residences in the United States and were selected for use in the indoor dust monitoring assessment as described in Section 4.1. Two studies combined different indoor environments in the results and were not used in the analysis. The study rating per the exposure systematic review criteria is provided in in Table 5-2. The systematic review ratings for the studies are high and medium, indicating good reporting and description of the monitoring from the study 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 number of samples within each study and multiple localities are used to assign a robust 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

Studies Used in Monitoring Indoor Analysis	Systematic Review Rating	Confidence in Data Used	Confidence in Model Inputs		Weight of Scientific Evidence Conclusion
			Body Weight [a]	Dust Ingestion Rate [b]	
Wilson et al. (2003)	Medium	Moderate	Robust	Moderate	Moderate
Guo and Kannan (2011)	High	Slight			Moderate
Dodson et al. (2015)	Medium	Moderate			Moderate
Bi et al. (2015)	High	Robust			Robust
Bi et al. (2018)	High	Moderate			Moderate
Hammel et al. (2019)	High	Robust			Robust

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

Table 5-2 presents the level of confidence in the data quality of the input datasets for estimating dust ingestion from monitoring data, including the BBP 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 EPA has determined that it is unlikely that the uncertainties could have a significant effect on the exposure estimate.
- Moderate confidence means the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure estimates, but uncertainties could have an effect on the exposure estimate.
- Slight confidence means there is an absence of complete information. There may be significant uncertainty in the underlying data that needs to be considered.

These confidence conclusions were derived from a combination of systematic review (*i.e.*, the quality determinations for individual studies) and professional judgment (Table 5-2).

In Wilson et al. (2003) (systematic review rating of medium), monitoring data was collected in Durham, North Carolina, for BBP in children's homes. This study sampled nine homes as well as nine hand wipe samples. House floor dust samples were collected in the areas indicated by the teacher or parent as being where the children played most often. Although these samples could be representative of the general U.S. population, the small sample size and lack of geographic diversity, selection of certain types of homes for the children in the study add to the uncertainty. Because of these uncertainties, EPA has assigned moderate confidence to the use of this model input.

In Guo and Kannan (2011) (systematic review rating of high), monitoring data was collected in Albany, New York, for BBP between 2007 and 2008 for 33 houses. Dust samples were collected by sweeping the floor and wiping the top of furniture as well as from vacuum cleaner bags of several homes. Information was not provided about the type of housing and if it is representative of the general U.S. population. Because of this uncertainty, EPA has assigned moderate confidence to the use of this model input.

In Dodson et al. (2015) (systematic review rating of medium), monitoring data were collected in Richmond and Bolinas, California, for BBP from the California Household Exposure Study (CAHES) conducted in 2006. This study sampled 49 nonsmoking homes in a low-income urban community and a rural community around the San Francisco area. Samples were collected by slowly dragging a crevice tool just above the surface of rugs, upholstery, wood floors, windowsills, ceiling fans, and furniture in the primary living areas of the home for approximately 30 minutes. Although these samples collect indoor dust samples from an existing study, the low income and rural population studied might not be representative of the general U.S. public. Because of this uncertainty, EPA has assigned moderate confidence to the use of this model input.

In Bi et al. (2015) (systematic review rating of high), monitoring data were collected from Dover, Delaware, for BBP in 2013. This study sampled 10 houses with floor materials of carpet, hardwood, or a combination of both. The study also indicated that the houses did not have a custodian for daily cleaning. Dust samples were collected using a bagged vacuum cleaner through an easily cleaned suction tube. Before each sampling, the internal surface of the suction tube was cleaned using an animal-hair brush and a piece of clean cloth, and a new bag was placed for dust collection. EPA believes these samples may not be a general representation of the U.S. population due to small number of samples and lack of geographic variability. Because of this, the Agency has assigned robust confidence to the use of this model input.

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

Monitoring data collected in the United States were identified for BBP, from the Toddlers' Exposure to SVOCs in the Indoor Environment (TESIE) study conducted between 2014 and 2016 (Hammel et al., 2019) (systematic review rating of high). This study sampled 190 residences in Durham, North Carolina, and included vacuum dust sampling as well as hand wipes and urine samples. Households were selected from participants in the Newborn Epigenetics Study, which is a prospective pregnancy cohort that began

in 2005 and recruited pregnant women who received services at Duke obstetrics facilities. While these facilities are associated with a teaching hospital and university, services are not restricted to students, and the demographic characteristics of the TIESIE study population match those of the Durham community (see Table 1 in Hammel et al. (2019)). Because this study carefully selected participants to avoid oversampling subpopulations and investigated a relatively large number of residences for a study of this type, and because EPA identified no reason to believe that households in the study location (Durham, North Carolina) would represent an outlier population that would not adequately represent the consumer practices of the broader U.S. public, the Agency assigned robust confidence to the use of this model input.

Body weight data were 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 National Health and Nutrition Examination Survey (NHANES) dataset, 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* (U.S. EPA, 2011c) for children under aged less than 1 year but diverge above this age (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.

Taken as a whole, with robust confidence in the BBP concentration monitoring data in indoor residential dust from Hammel et al. (2019), robust confidence in body weight data from the *Exposure Factors Handbook* U.S. EPA (2011b), and moderate confidence in dust intake data from Özkaynak et al. (2022), EPA has assigned a weight of scientific evidence rating of robust confidence in our estimates of daily BBP intake rates from ingestion of indoor dust in residences.

5.2.1 Assumptions in Estimating Intakes from Indoor Dust Monitoring

5.2.1.1 Assumptions for Monitored BBP Concentrations in Indoor Dust

The BBP concentrations in indoor dust were derived from the seven studies in Table 5-2. Four of the studies rated moderate and two robust in confidence in data used. Notably, both studies rated as moderate were assumed to not be representative of a typical U.S. household whereas the robust studies were assumed to be representative. Samples were either taken from the living room or children's room, where the children's room was identified as the room in which the child(ren) residing in the home spent the most time. A key assumption made in this analysis is that dust concentrations in playrooms and living rooms are representative of those in the remainder of the home.

5.2.1.2 Assumptions for Body Weights

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

5.2.1.3 Assumptions for Dust Ingestion Rates

To estimate daily intake of BBP 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 old. A probabilistic approach was used in the Özkaynak et al. (2022) study to assign exposure parameters, including behavioral and biological variables. The exposure parameters are summarized in Table 5-3 and the statistical distributions chosen are reproduced in detail in the supplemental material included 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 life stage.
[b] Variable only applies to children aged <2 years.

5.2.2 Uncertainties in Estimating Intakes from Monitoring Data

5.2.2.1 Uncertainties for Monitored BBP Concentrations in Indoor Dust

For all six studies, there is uncertainty for sampling biases, which can include the choice of study location, choosing only households that contain children, and by differences among the households that chose to participate in the study. For example, Hammel et al. (2019) sampled residential house dust in 190 households in Durham, North Carolina, from a population selected from an existing pregnancy cohort study. In addition, differences in consumer behaviors, housing type and quality, tidiness, and other variables that affect BBP concentrations in household dust are possible between participating households and the general population.

5.2.2.2 Uncertainties for Body Weights

Body weights were obtained from the *Exposure Factors Handbook*, which contains data from the 1999 to 2006 NHANES (U.S. EPA, 2011b). Body weights were aggregated across life stages 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 BBP dose per unit body weight, because actual body weights in the U.S. population may be larger than those assumed in this analysis.

5.2.2.3 Uncertainties for Dust Ingestion Rates

Dust ingestion rates were obtained from Özkaynak et al. (2022), which uses mechanistic methods (the SHEDS Model) to estimate dust ingestion using a range of parameters (Table 5-3). 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 to <1 Month	1 to <3 Months	3 to <6 Months	6 Months to <1 Year	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 to <16 Years	16 to <21 Years
Central tendency dust ingestion (mg/day)	Özkaynak et al. (2022)	19	21	23	26	23	14	15	13	8.8	3.5
	U.S. EPA (2017)	20	20	20	20	50	30	30	30	20 [a]	20

[a] The intake for an 11-year-old based on the *Exposure Factors Handbook* is 30 mg/day. The age ranges do not align between the 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,* while the estimate for children aged between 1 month and 1 year 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."

5.2.2.4 Uncertainties in Interpretation of Monitored BBP Intake Estimates

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

- Samples may have been collected at exposure times or for exposure durations not expected to be consistent with a presumed hazard based on a specified exposure time or duration.
- Samples may have been collected at a time or location when there were multiple sources of BBP that included non-TSCA COUs.
- None of the identified monitoring data contained source apportionment information that could be used to determine the fraction of BBP in dust samples that resulted from a particular TSCA or non-TSCA COU. Therefore, these monitoring data represent background concentrations of BBP 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), which 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.

6 CONCLUSION AND STEPS TOWARD RISK CHARACTERIZATION

Indoor Dust

For the indoor exposure assessment, EPA considered modeling and monitoring data. Monitoring data are expected to represent aggregate exposure to BBP in dust resulting from all sources present in a home. Although not a good indicator of individual contributions of specific COUs, it provides a real-world indicator of total exposure through dust. For the modeling assessment of indoor dust exposures and estimating contribution to dust from individual COUs, EPA recreated plausible indoor environment using consumer products and articles commonly present in indoor spaces inhalation exposure from toys, flooring, and synthetic leather furniture that include a consideration of dust collected on the surface of a relatively large area, like flooring, and furniture, but also multiple toys and wires collecting dust with BBP and subsequent inhalation and ingestion.

The monitoring estimates were used as a comparator to show that the modeled BBP exposure estimates were health protective relative to residential monitored exposures (Table 4-4). This comparison was a key consideration to the robust confidence in the overall health protectiveness of the exposure assessment for ingestion of BBP in indoor dust. The individual COU-modeled scenarios had a moderate to robust confidence in the exposure dose results and protectiveness of parameters used. Thus, the COU scenarios of the articles used in the indoor assessment were utilized in risk estimate calculations.

Consumer

All COU exposure dose results summarized in Section 3 and the *BBP Consumer Risk Calculator* (U.S. EPA, 2025c) have a moderate to robust confidence and therefore can be used for risk estimate calculations and to determine risk to the various life stages. The consumer assessment has low-, medium-, and high-exposure scenarios that 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 BBP from products/articles to sweat and skin. Low- and medium-exposure scenarios represent less intensity in use patterns, mouthing behaviors, and conditions that promote BBP migration to sweat and skin, capturing populations with different lifestyles.

7 REFERENCES

ACC. (2019). Global automotive declarable substance list 2019. MS Excel file. Version 1.1. Revised 3/12/2019. https://www.gadsl.org/

Adgate, JL; Weisel, C; Wang, Y; Rhoads, GG; Lioy, PJ. (1995). Lead in house dust: Relationships between exposure metrics. Environ Res 70: 134-147. http://dx.doi.org/10.1006/enrs.1995.1058

Anderson, WAC; Castle, L; Scotter, MJ; Massey, RC; Springall, C. (2001). A biomarker approach to measuring human dietary exposure to certain phthalate diesters. Food Addit Contam 18: 1068-1074. http://dx.doi.org/10.1080/02652030110050113

Armored AutoGroup Inc. (2015). Safety Data Sheet - STP Power Steering Fluid and Stop Leak. Armored AutoGroup Inc. https://docs.google.com/viewerng/viewer?url=https://www.whatsinproducts.com//files/brands_pdf/1476804751.pdf&toolbar=1

Assy, Z; Klop, C; Brand, HS; Hoogeveen, RC; Koolstra, JH; Bikker, FJ. (2020). Determination of intra-oral surface areas by cone-beam computed tomography analysis and their relation with anthrometric measurements of the head. Surg Rad Anat 42: 1063-1071. http://dx.doi.org/10.1007/s00276-020-02530-7

Aurisano, N; Fantke, P; Huang, L; Jolliet, O. (2022). Estimating mouthing exposure to chemicals in children's products. J Expo Sci Environ Epidemiol 32: 94-102. http://dx.doi.org/10.1038/s41370-021-00354-0

Beamer, P; Canales, RA; Leckie, JO. (2009). Developing probability distributions for transfer efficiencies for dermal exposure [Review]. J Expo Sci Environ Epidemiol 19: 274-283. http://dx.doi.org/10.1038/jes.2008.16

Bi, C; Maestre, JP; Li, H; Zhang, G; Givehchi, R; Mahdavi, A; Kinney, KA; Siegel, J; Horner, SD; Xu, Y. (2018). Phthalates and organophosphates in settled dust and HVAC filter dust of U.S. low-income homes: Association with season, building characteristics, and childhood asthma. Environ Int 121: 916-930. http://dx.doi.org/10.1016/j.envint.2018.09.013

Bi, X; Yuan, S; Pan, X; Winstead, C; Wang, Q. (2015). Comparison, association, and risk assessment of phthalates in floor dust at different indoor environments in Delaware, USA. J Environ Sci Health A Tox Hazard Subst Environ Eng 50: 1428-1439. http://dx.doi.org/10.1080/10934529.2015.1074482

BJB Enterprises. (2019). SDS - 6840 ULTRA BLACK. BJB Enterprises Inc.

BJB Enterprises. (2021). Safety Data Sheet (SDS): TC-680 PART B. Tustin, CA. https://bjbmaterials.com/pub/media/wysiwyg/pdfs/Shore-A-Aliphatics/TC-680_Part_B.pdf

BJB Enterprises. (2022). Safety Data Sheet (SDS): TC-690 PART B. Tustin, CA. https://bjbmaterials.com/pub/media/wysiwyg/pdfs/Shore-A-Aliphatics/TC-690_Part_B.pdf

Black, K; Shalat, SL; Freeman, NCG; Jimenez, M; Donnelly, KC; Calvin, JA. (2005). Children's mouthing and food-handling behavior in an agricultural community on the US/Mexico border. J Expo Anal Environ Epidemiol 15: 244-251. http://dx.doi.org/10.1038/sj.jea.7500398

Britz, MB; Maibach, HI; Anjo, DM. (1980). Human percutaneous penetration of hydrocortisone: the vulva. Arch Dermatol Res 267: 313-316. http://dx.doi.org/10.1007/BF00403852

CDC. (2013). National Health and Nutrition Examination Survey Data (NHANES) [Database].

CDC. (2021). Child development: Positive parenting tips. Available online at https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/index.html (accessed April 3, 2024).

Collins, LM; Dawes, C. (1987). The surface area of the adult human mouth and thickness of the salivary film covering the teeth and oral mucosa. J Dent Res 66: 1300-1302. http://dx.doi.org/10.1177/00220345870660080201

CPSC. (2015). CPSC staff statement on the toxicology excellence for risk assessment report, "exposure assessment: composition, production, and use of phthalates". https://www.cpsc.gov/s3fs-public/pdfs/TERAReportPhthalates.pdf
Danish EPA. (2010a). Phthalates in plastic sandals. https://www2.mst.dk/udgiv/publications/2010/978-87-92708-67-0/pdf/978-87-92708-66-3.pdf
Danish EPA. (2010b). Survey No. 108: Phthalates in products with large surfaces. Copenhagen, Denmark: Danish Environmental Protection Agency. https://www2.mst.dk/udgiv/publications/2010/978-87-92708-71-7/pdf/978-87-92708-70-0.pdf
Danish EPA. (2011). Annex XV restriction report: Proposal for a restriction, version 2. Substance name: bis(2-ehtylhexyl)phthlate (DEHP), benzyl butyl phthalate (BBP), dibutyl phthalate (DBP), diisobutyl phthalate (DIBP). Copenhagen, Denmark: Danish Environmental Protection Agency :: Danish EPA. https://echa.europa.eu/documents/10162/c6781e1e-1128-45c2-bf48-8890876fa719
Danish EPA. (2020). Survey of unwanted additives in PVC products imported over the internet. (Environmental Project No 2149). Denmark: Ministry of the Environment and Food of Denmark. https://www2.mst.dk/Udgiv/publications/2020/10/978-87-7038-237-3.pdf
DAP Products. (2024). Technical Bulletin: DAP Premium Polyurethane Roof & Flashing Sealant. Baltimore, MD. https://www.whatsinproducts.com/types/type_detail/1/10348/standard/DAP%20Premium%20Polyurethane%20Roof%20&%20Flashing%20Sealant/04-008-098
DeLima Associates. (2018a). Quikrete Concrete Patching Compound, 8650-35,-01/30/2018. Available online at https://www.whatsinproducts.com/types/type_detail/1/21449/standard/p%3EQuikrete%20Concrete%20Patching%20Compound,%208650-35,-01/30/2018/p%3E/17-002-181
DeLima Associates. (2018b). Sakrete Blacktop Repair Tube-01/31/2018. Available online at https://www.whatsinproducts.com/types/type_detail/1/21412/standard/p%3ESakrete%20Blacktop%20Repair%20Tube-01/31/2018/p%3E/21-006-089
Dodson, RE; Camann, DE; Morello-Frosch, R; Brody, JG; Rudel, RA. (2015). Semivolatile organic compounds in homes: strategies for efficient and systematic exposure measurement based on empirical and theoretical factors. Environ Sci Technol 49: 113-122. http://dx.doi.org/10.1021/es502988r
Dodson, RE; Nishioka, M; Standley, LJ; Perovich, LJ; Brody, JG; Rudel, RA. (2012). Endocrine disruptors and asthma-associated chemicals in consumer products. Environ Health Perspect 120: 935-943. http://dx.doi.org/10.1289/ehp.1104052
DuPont. (2006a). Polyvinyl chloride film plasticized with butyl benzyl phthalate: In vitro dermal absorption rate testing. (DuPont-17805). Independence, OH: Ferro Corporation, Inc.
DuPont. (2006b). [Sanitized] Butyl benzyl phthalate: In vitro dermal absorption rate testing. (DuPont-17755). Independence, OH: Ferro Corporation, Inc.
ECHA. (2013). Evaluation of new scientific evidence concerning DINP and DIDP in relation to entry 52 of Annex XVII to REACH Regulation (EC) No 1907/2006. Helsinki, Finland. http://echa.europa.eu/documents/10162/31b4067e-de40-4044-93e8-9c9ff1960715
ECJRC. (2007). European Union Risk Assessment Report: Benzyl butyl phthalate (CAS No: 85-68-7, EINECS: 201-622-7). (EUR 22773 EN). Luxembourg: European Commission. https://echa.europa.eu/documents/10162/bad5c928-93a5-4592-a4f6-e02c5e89c299
Eigenberg, DA; Bozigian, HP; Carter, DE; Sipes, IG. (1986). Distribution, excretion, and metabolism of butylbenzyl phthalate in the rat. J Toxicol Environ Health 17: 445-456. http://dx.doi.org/10.1080/15287398609530839
Elmers. (2009). Safety Data Sheet - Elmer's Model and Hobby Cement. Available online at https://doc-08-30-apps-viewer.googleusercontent.com/viewer/secure/pdf/rfpp02b7f9un6mm23belclv37oie5p61/tjnusceg

74smsa8bda4tftrirv5pvo4o/1558054275000/lantern/16419981854221299223/ACFrOgB0a_ANU35K2-ELmn-YVHLdMBCeoSFHUAdxE1B52BgvhS3gDzlrGSYSOclI0Q237V-VFR955UmAlaMM5BsM3UC-Rol3B2E7RAaC9Mp0P4GSIOKFnWY9acbqWIQcbzMsPS4HkggnHz9ouqFy?print=true&nonce=7vle77pcahu72&user=16419981854221299223&hash=a8dankrmms6gbe8p7vgapp4odvmspe8c

Elsisi, AE; Carter, DE; Sipes, IG. (1989). Dermal absorption of phthalate diesters in rats. Fundam Appl Toxicol 12: 70-77. http://dx.doi.org/10.1016/0272-0590(89)90063-8

ERG. (2016). Peer review of EPA's Consumer Exposure Model and draft user guide (final peer review report). Washington, DC: U.S. Environmental Protection Agency.

Ford Motor Company. (2019). SDS - Lacquer Touch-Up Paint - Clear Topcoat.

Freeman, NCG; Jimenez, M; Reed, KJ; Gurunathan, S; Edwards, RD; Roy, A; Adgate, JL; Pellizzari, ED; Quackenboss, J; Sexton, K; Lioy, PJ. (2001). Quantitative analysis of children's microactivity patterns: The Minnesota Children's Pesticide Exposure Study. J Expo Anal Environ Epidemiol 11: 501-509. http://dx.doi.org/10.1038/sj.jea.7500193

Greene, MA. (2002). Mouthing times among young children from observational data. Bethesda, MD: U.S. Consumer Product Safety Commission.

Guo, Y; Kannan, K. (2011). Comparative assessment of human exposure to phthalate esters from house dust in China and the United States. Environ Sci Technol 45: 3788-3794. http://dx.doi.org/10.1021/es2002106

Gurunathan, S; Robson, M; Freeman, N; Buckley, B; Roy, A; Meyer, R; Bukowski, J; Lioy, PJ. (1998). Accumulation of chlorpyrifos on residential surfaces and toys accessible to children. Environ Health Perspect 106: 9-16. http://dx.doi.org/10.2307/3433627

Hammel, SC; Levasseur, JL; Hoffman, K; Phillips, AL; Lorenzo, AM; Calafat, AM; Webster, TF; Stapleton, HM. (2019). Children's exposure to phthalates and non-phthalate plasticizers in the home: The TESIE study. Environ Int 132: 105061. http://dx.doi.org/10.1016/j.envint.2019.105061

HCC Holdings Inc. (2015). SDS - Hercules Plumber's Caulk - White Linen. HCC Holdings Inc.

Henry Company. (2015). SDS - AIR BLOC 33. Henry Company.

Herbenick, D; Fu, TC; Patterson, C. (2023). Sexual repertoire, duration of partnered sex, sexual pleasure, and orgasm: Findings from a US nationally representative survey of adults. J Sex Marital Ther 49: 369-390. http://dx.doi.org/10.1080/0092623X.2022.2126417

Holmes, KK, Jr; Shirai, JH; Richter, KY; Kissel, JC. (1999). Field measurement of dermal soil loadings in occupational and recreational activities. Environ Res 80: 148-157. http://dx.doi.org/10.1006/enrs.1998.3891

Huang, L; Fantke, P; Ernstoff, A; Jolliet, OA. (2017). Quantitative property-property relationship for the internal diffusion coefficients of organic compounds in solid materials. Indoor Air 27: 1128-1140. http://dx.doi.org/10.1111/ina.12395

Hubal, EA; Nishioka, MG; Ivancic, WA; Morara, M; Egeghy, PP. (2008). Comparing surface residue transfer efficiencies to hands using polar and nonpolar fluorescent tracers. Environ Sci Technol 42: 934-939. http://dx.doi.org/10.1021/es071668h

Identity Group. (2017). SDS - HANDSTAMP - BLUE. Identity Group.

Kissel, JC; Richter, KY; Fenske, RA. (1996a). Factors affecting soil adherence to skin in hand-press trials. Bull Environ Contam Toxicol 56: 722-728. http://dx.doi.org/10.1007/s001289900106

Kissel, JC; Richter, KY; Fenske, RA. (1996b). Field measurement of dermal soil loading attributable to various activities: Implications for exposure assessment. Risk Anal 16: 115-125. http://dx.doi.org/10.1111/j.1539-6924.1996.tb01441.x

Kissel, JC; Shirai, JH; Richter, KY; Fenske, RA. (1998). Investigation of dermal contact with soil in controlled trials. Journal of Soil Contamination 7: 737-752. http://dx.doi.org/10.1080/10588339891334573

Leckie, JO; Naylor, KA; Canales, RA; Ferguson, AC; Cabrera, NL; Hurtado, AL; Lee, K; Lin, AY; Ramirez, JD; VM, V. (2000). Quantifying children's microlevel activity data from existing videotapes. (Reference No. U2F112OT-RT. 2000). Washington, DC: U.S. Environmental Protection Agency.

MEMA. (2019). Comment submitted by Catherine M. Wilmarth, Attorney, Alliance of Automobile Manufacturers and Laurie Holmes, Senior Director, Environmental Policy, Motor & Equipment Manufacturers Association (MEMA). (EPA-HQ-OPPT-2019-0131-0022). Alliance of Automobile Manufacturers and Motor & Equipment Manufacturers Association. https://www.regulations.gov/document?D=EPA-HQ-OPPT-2019-0131-0022

Momentive. (2017). Safety Data Sheet (SDS): GE7000. New Smyrna Beach, FL: Momentive Performance Materials Inc.

Multi-Tech Products Corp. (2015). SDS - REPAIR AND REFINISHING SPRAY. Multi-Tech Products Corp.

Nativelle, C; Picard, K; Valentin, I; Lhuguenot, JC; Chagnon, MC. (1999). Metabolism of n-butyl benzyl phthalate in the female Wistar rat. Identification of new metabolites. Food Chem Toxicol 37: 905-917. http://dx.doi.org/10.1016/S0278-6915(99)00071-X

NICNAS. (2015). Priority existing chemical assessment report no. 40: Butyl benzyl phthalate. (PEC40). Sydney, Australia: Australian Government Department of Health and Ageing. https://www.industrialchemicals.gov.au/sites/default/files/PEC40-Butyl-benzyl-phthalate-BBP.pdf

Niino, T; Asakura, T; Ishibashi, T; Itoh, T; Sakai, S; Ishiwata, H; Yamada, T; Onodera, S. (2003). A simple and reproducible testing method for dialkyl phthalate migration from polyvinyl chloride products into saliva simulant. Shokuhin Eiseigaku Zasshi 44: 13-18. http://dx.doi.org/10.3358/shokueishi.44.13

Niino, T; Ishibashi, T; Itho, T; Sakai, S; Ishiwata, H; Yamada, T; Onodera, S. (2001). Monoester formation by hydrolysis of dialkyl phthalate migrating from polyvinyl chloride products in human saliva. J Health Sci 47: 318. http://dx.doi.org/10.1248/jhs.47.318

NLM. (2015). PubChem: Hazardous Substance Data Bank: Butyl benzyl phthalate, 85-68-7. Available online at https://pubchem.ncbi.nlm.nih.gov/compound/2347 (accessed March 19, 2024).

Özkaynak, H; Glen, G; Cohen, J; Hubbard, H; Thomas, K; Phillips, L; Tulve, N. (2022). Model based prediction of age-specific soil and dust ingestion rates for children. J Expo Sci Environ Epidemiol 32: 472-480. http://dx.doi.org/10.1038/s41370-021-00406-5

Ozkaynak, H; Xue, J; Zartarian, VG; Glen, G; Smith, L. (2011). Modeled estimates of soil and dust ingestion rates for children. Risk Anal 31: 592-608. http://dx.doi.org/10.1111/j.1539-6924.2010.01524.x

Permatex. (2020). Safety Data Sheet (SDS): 126VR DISC BRAKE QUIET 0.25 FL.OZ POUCH. Solon, OH. https://www.permatex.com/wp-content/uploads/sds/80729.pdf

Protecto Wrap. (2020). Safety Data Sheet (SDS): Protecto sealant 25XL [Fact Sheet]. Denver, CO. https://protectowrap.com/wp-content/uploads/2020/06/Protecto-Sealant-25XL-0623_2020.pdf

Quikrete. (2015a). Safety Data Sheet - MORTAR REPAIR. Quikrete Companies. https://images.homedepot-static.com/catalog/pdfImages/22/226b5342-3fd0-4ea6-b286-5565eb06cd48.pdf

Quikrete. (2015b). Safety Data Sheet - PRE-MIXED STUCCO PATCH. Quikrete Companies. https://images.homedepot-static.com/catalog/pdfImages/4b/4bc92620-8400-46fb-adc7-9715eb219057.pdf

Rodes, CE; Newsome, JR; Vanderpool, RW; Antley, JT; Lewis, RG. (2001). Experimental methodologies and preliminary transfer factor data for estimation of dermal exposures to particles. J Expo Anal Environ Epidemiol 11: 123-139. http://dx.doi.org/10.1038/sj.jea.7500150

Royal Adhesives & Sealants. (2017). SDS - Double Bubble Urethane High Peel. Royal Adhesives & Sealants.

Rudel, RA; Brody, JG; Spengler, JD; Vallarino, J; Geno, PW; Sun, G; Yau, A. (2001). Identification of selected hormonally active agents and animal mammary carcinogens in commercial and residential air and dust samples. J Air Waste Manag Assoc 51: 499-513. http://dx.doi.org/10.1080/10473289.2001.10464292

Scott, RC; Dugard, PH; Ramsey, JD; Rhodes, C. (1987). In vitro absorption of some o-phthalate diesters through human and rat skin. Environ Health Perspect 74: 223-227. http://dx.doi.org/10.2307/3430452

Sipe, JM; Amos, JD; Swarthout, RF; Turner, A; Wiesner, MR; Hendren, CO. (2023). Bringing sex toys out of the dark: Exploring unmitigated risks. Micropl&Nanopl 3: 6. http://dx.doi.org/10.1186/s43591-023-00054-6

Smith, SA; Norris, B. (2003). Reducing the risk of choking hazards: Mouthing behaviour of children aged 1 month to 5 years. Inj Contr Saf Promot 10: 145-154. http://dx.doi.org/10.1076/icsp.10.3.145.14562

Smooth-On. (2022). Safety Data Sheet (SDS) - Part A: Smooth-Cast 325. Macungie, PA. https://www.smooth-on.com/msds/files/Smooth-Cast_325.pdf

Stopford, W; Turner, J; Cappellini, D. (2003). Determination of the magnitude of clay to skin and skin to mouth transfer of phthalates associated with the use of polymer clays. Durham, NC: Duke University Medical Center.

Sugino, M; Hatanaka, T; Todo, H; Mashimo, Y; Suzuki, T; Kobayashi, M; Hosoya, O; Jinno, H; Juni, K; Sugibayashi, K. (2017). Safety evaluation of dermal exposure to phthalates: Metabolism-dependent percutaneous absorption. Toxicol Appl Pharmacol 328: 10-17. http://dx.doi.org/10.1016/j.taap.2017.05.009

Tremco Canadian Sealants. (2015). SDS - DYMONIC FC ANODIZED ALUMINUM. Tremco Canadian Sealants.

Tsou, MC; Özkaynak, H; Beamer, P; Dang, W; Hsi, HC; Jiang, CB; Chien, LC. (2015). Mouthing activity data for children aged 7 to 35 months in Taiwan. J Expo Sci Environ Epidemiol 25: 388-398. http://dx.doi.org/10.1038/jes.2014.50

Tsou, MC; Özkaynak, H; Beamer, P; Dang, W; Hsi, HC; Jiang, CB; Chien, LC. (2017). Mouthing activity data for children age 3 to <6 years old and fraction of hand area mouthed for children age <6 years old in Taiwan. J Expo Sci Environ Epidemiol 28: 182-192. http://dx.doi.org/10.1038/jes.2016.87

U.S. EPA. (2006). A framework for assessing health risk of environmental exposures to children. (EPA/600/R-05/093F). Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=158363

U.S. EPA. (2011a). Exposure Factors Handbook, Chapter 6: Inhalation rates. Washington, DC. https://www.epa.gov/expobox/exposure-factors-handbook-chapter-6

U.S. EPA. (2011b). Exposure Factors Handbook, Chapter 8: Body weight studies. Washington, DC. https://www.epa.gov/expobox/exposure-factors-handbook-chapter-8

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

U.S. EPA. (2012). Standard operating procedures for residential pesticide exposure assessment. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs. https://www.epa.gov/sites/default/files/2015-08/documents/usepa-opp-hed_residential_sops_oct2012.pdf

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

U.S. EPA. (2019a). Chemical data reporting (2012 and 2016 public CDR database). Washington, DC: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. Retrieved from https://www.epa.gov/chemical-data-reporting

U.S. EPA. (2019b). Synthetic turf field recycled tire crumb rubber research under the Federal Research Action Plan, Final report part 1: Tire crumb rubber characterization appendices, volume 2. (EPA/600/R-19/051.2). Washington, DC: U.S. Environmental Protection Agency, ATSDR, CDC. https://www.epa.gov/sites/default/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_2.pdf

U.S. EPA. (2019c). Synthetic turf field recycled tire crumb rubber research under the Federal Research Action Plan, Final report part 1: Tire crumb rubber characterization, volume 1. (EPA/600/R-19/051.1). Washington, DC: U.S. Environmental Protection Agency, ATSDR, CDC. https://www.epa.gov/sites/default/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_1.pdf

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

U.S. EPA. (2023). Consumer Exposure Model (CEM) Version 3.2 User's Guide. Washington, DC. https://www.epa.gov/tsca-screening-tools/consumer-exposure-model-cem-version-32-users-guide

U.S. EPA. (2024a). Draft Physical Chemistry Assessment for Butyl benzyl phthalate (BBP). Washington, DC: Office of Pollution Prevention and Toxics.

U.S. EPA. (2024b). Synthetic turf field recycled tire crumb rubber research under the Federal Research Action Plan, Final report part 2: Exposure characterization, volume 1. (EPA/600/R 24/020.1). Washington, DC: U.S. Environmental Protection Agency, ATSDR, CDC. https://www.epa.gov/system/files/documents/2024-04/tcrs-exposure-characterization-volume-1.pdf

U.S. EPA. (2024c). Synthetic turf field recycled tire crumb rubber research under the Federal Research Action Plan: Final report part 2 – Exposure characterization appendices, Volume 2. (EPA/600/R-24/020.2). Washington, DC: U.S. Environmental Protection Agency, ATSDR, CDC. https://www.epa.gov/system/files/documents/2024-04/tcrs-exposure-characterization-volume-2.pdf

U.S. EPA. (2025a). Draft Consumer Exposure Analysis for Butyl Benzyl Phthalate (BBP). Washington, DC: Office of Pollution Prevention and Toxics. https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0501-0107

U.S. EPA. (2025b). Draft Consumer Exposure Analysis for Dibutyl Phthalate (DBP). Washington, DC: Office of Pollution Prevention and Toxics. https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0503-0100

U.S. EPA. (2025c). Draft Consumer Risk Calculator for Butyl Benzyl Phthalate (BBP). Washington, DC: Office of Pollution Prevention and Toxics. https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0501-0106
U.S. EPA. (2025d). Draft Risk Evaluation for Butyl Benzyl Phthalate (BBP). Washington, DC: Office of Pollution Prevention and Toxics. https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0501-0089
U.S. EPA. (2025e). Science Advisory Committee on Chemicals (SACC) meeting minutes and final report - Peer Review of the Draft Risk Evaluations of Dibutyl phthalate (DBP), Di(2-ethylhexyl) phthalate (DEHP), and Dicyclohexyl phthalate (DCHP), and the Technical Support Documents for Butylbenzyl phthalate (BBP) and Diisobutyl phthalate (DIBP). Washington, DC. https://www.regulations.gov/docket/EPA-HQ-OPPT-2024-0551
VPIRG. (2002). Hidden hazards: Health impacts of toxins in polymer clays. Washington, DC: U.S. Public Interest Research Group. https://pirg.org/resources/hidden-hazards/
W.M. Barr. (2015). SDS - Klean-Strip Mask & Peel Paint Booth Coating. W.M. Barr.
Walmart. (2019). STP 17925 Power Steering Fluid & Stop Leak. Available online at https://www.walmart.com/ip/STP-17925-Power-Steering-Fluid-Stop-Leak-12-fl-oz-Pack-of-2/719948499?wmlspartner=wlpa&selectedSellerId=11059&adid=22222222227267003159&wl0=&wl1=g&wl2=c&wl3=317906743368&wl4=aud-566049426705:pla-615850579644&wl5=9028775&wl6=&wl7=&wl8=&wl9=pla&wl10=125198037&wl11=online&wl12=719948499&wl13=&veh=sem&gclid=CjwKCAjwlPTmBRBoEiwAHqpvhd7vZEzAi7feziUopz7mtg4fiMy9E0pYR8WsAiZCIu5zqjCWbpYcYBoC5XAQAvD_BwE
Wilson, NK; Chuang, JC; Lyu, C. (2001). Levels of persistent organic pollutants in several child day care centers. J Expo Anal Environ Epidemiol 11: 449-458. http://dx.doi.org/10.1038/sj.jea.7500190
Wilson, NK; Chuang, JC; Lyu, C; Menton, R; Morgan, MK. (2003). Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home. J Expo Anal Environ Epidemiol 13: 187-202. http://dx.doi.org/10.1038/sj.jea.7500270
Wilsonart. (2013). SDS - Wilsonart Color Matched Caulk. Wilsonart LLC.
Wormuth, M; Scheringer, M; Vollenweider, M; Hungerbuhler, K. (2006). What are the sources of exposure to eight frequently used phthalic acid esters in Europeans? Risk Anal 26: 803-824. http://dx.doi.org/10.1111/j.1539-6924.2006.00770.x
WSDE. (2020). High Priority Chemicals Data System (HPCDS) [Database]. Retrieved from https://hpcds.theic2.org/Search
Xue, J; Zartarian, V; Moya, J; Freeman, N; Beamer, P; Black, K; Tulve, N; Shalat, S. (2007). A meta-analysis of children's hand-to-mouth frequency data for estimating nondietary ingestion exposure. Risk Anal 27: 411-420. http://dx.doi.org/10.1111/j.1539-6924.2007.00893.x
Xue, J; Zartarian, V; Tulve, N; Moya, J; Freeman, N; Auyeung, W; Beamer, P. (2010). A meta-analysis of children's object-to-mouth frequency data for estimating non-dietary ingestion exposure. J Expo Sci Environ Epidemiol 20: 536-545. http://dx.doi.org/10.1038/jes.2009.42
Zartarian, VG; Ferguson, AC; Leckie, JO. (1997). Quantified dermal activity data from a four-child pilot field study. J Expo Anal Environ Epidemiol 7: 543-552.
Zartarian, VG; Xue, J; Ozkaynak, H; Dang, W; Glen, G. (2005). Probabilistic exposure assessment for children who contact CCA-treated playsets and decks using the stochastic human exposure and dose simulation model for the wood preservative exposure scenario (SHEDS-Wood). (NTIS/02937833). Washington, DC: U.S. Environmental Protection Agency.

APPENDICES

Appendix A ACUTE, CHRONIC, AND INTERMEDIATE DOSE RATE EQUATIONS

The equations provided in this section were taken from the CEM user guide and associated appendices (accessed November 26, 2025).

A.1 Acute Dose Rate

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

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

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

Where:

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

For the ADR calculations, an averaging time of 1 day is used; the ADR therefore represents the maximum time-integrated dose over a 24-hour period during the exposure event. 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. CEM calculates all possible ADRs over the 60-day modeling period as running 24-hour integrations (*i.e.*, 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:

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

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

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

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

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)
$BBPRP_{air\_max}$	=	Maximum BBP in RP concentration, air (µg/mg)
RP_{air_max}	=	Maximum respirable particle concentration, air (mg/m^3)
$FracTime$	=	Fraction of time in environment (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 h/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1,000 µg/mg)

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

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

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

Where:

ADR_{IAI}	=	Acute dose rate from ingestion and inhalation (mg/kg-day)
$BBPRP_{air\_max}$	=	Maximum BBP in RP concentration, air (µg/mg)
RP_{air_max}	=	Maximum RP concentration, air (mg/m^3)
IF_{TSP}	=	RP ingestion fraction (unitless)
$BBPDust_{air\_max}$	=	Maximum BBP in dust concentration, air (µg/mg)
$Dust_{air\_max}$	=	Maximum dust concentration, air (mg/m^3)
IF_{Dust}	=	Dust ingestion fraction (unitless)
$BBPAbr_{air\_avg}$	=	Maximum BBP in abraded particle concentration, air (µg/mg)
Abr_{air_avg}	=	Maximum abraded particle concentration, air (mg/m^3)
IF_{Abr}	=	Abraded particle ingestion fraction (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 h/day)
BW	=	Body weight (kg)
CF_2	=	Conversion factor (1000 mg/g)

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

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

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

Where:

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

See Section 2.1 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 BBP 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 particle-bound to BBP 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 BBP-containing dust. The model uses a weighted dust concentration, shown in Equation_Apx A-7.

Equation_Apx A-7. Acute Dust Concentration

$$Dust_{ac\_wgt} = \frac{\left(RP_{floor\_max} \times BBPRP_{floor\_max}\right) + \left(Dust_{floor\_max} \times BBPDust_{floor\_max}\right) + \left(AbArt_{floor\_max} \times BBPAbArt_{floor\_max}\right)}{\left(TSP_{floor\_max} + Dust_{floor\_max} + AbArt_{floor\_max}\right)}$$

Where:

$Dust_{ac\_wgt}$	=	Acute weighted dust concentration (µg/mg)
RP_{floor_max}	=	Maximum RP mass, floor (mg)
$BBPRP_{floor\_max}$	=	Maximum BBP in RP concentration, floor (µg/mg)
$Dust_{floor\_max}$	=	Maximum dust mass, floor (mg)
$BBPDust_{floor\_max}$	=	Maximum BBP in dust concentration, floor (µg/mg)
$AbArt_{floor\_max}$	=	Maximum abraded particles mass, floor (mg)
$DIBPAbArt_{floor\_max}$	=	Maximum floor dust BBP 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 BBP can volatilize from the BBP-containing article to the air and then partition to dust. Alternately, BBP 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 BBP 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 BBP in Dust

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

Where:

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

Once BBP 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 BBP in dust (mg/mg)
$FracTime$	=	Fraction of time in environment (unitless)
$DustIng$	=	Dust ingestion rate (mg/day)
BW	=	Body weight (kg)

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

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

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

Where:

ADR	=	Acute dose rate (mg/kg-day)
FQ_{ac}	=	Frequency of use, acute (events/day)
M	=	Mass of product used (g)
WF	=	Weight fraction of chemical in product (unitless)
F_{ing}	=	Fraction of product ingested (unitless)
CF_1	=	Conversion factor (1000 mg/g)
ED_{ac}	=	Exposure duration, acute (days)
AT_{ac}	=	Averaging time, acute (days)

BW = Body weight (kg)

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

A.2 Non-Cancer Chronic Dose

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

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

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

Where:

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

CEM uses two different inhalation rates, 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/h) [a]	Inhalation Rate After Use (m^3/h) [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	0.50
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] See Table 6-2, light intensity values, in (U.S. EPA, 2011a)
[b] See Table 6-1 in (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, 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

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

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)
$BBPRP_{air\_avg}$	=	Average BBP in RP concentration, air (µg/mg)
RP_{air_avg}	=	Average RP concentration, air (mg/m^3)
IF_{RP}	=	RP ingestion fraction (unitless)
$FracTime$	=	Fraction of time in environment (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 h/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 BBP 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 BBP 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

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

Where:

$CADD_{IAI}$	=	Chronic average daily dose (ingestion after inhalation, mg/kg-day)
$BBPRP_{air\_avg}$	=	Average BBP in RP concentration, air (µg/mg)
RP_{air_avg}	=	Average RP concentration, air (mg/m^3)
IF_{RP}	=	RP ingestion fraction (unitless)
$BBPDust_{air\_avg}$	=	Average BBP dust concentration, air (µg/mg)
$Dust_{air\_avg}$	=	Average dust concentration, air (mg/m^3)
IF_{Dust}	=	Dust ingestion fraction (unitless)
$BBPAbr_{air\_avg}$	=	Average BBP in abraded particle concentration, air (µg/mg)
Abr_{air_avg}	=	Average abraded particle concentration, air (mg/m^3)
IF_{Abr}	=	Abraded particle ingestion fraction (unitless)
$InhalAfter$	=	Inhalation rate after use (m^3/h)
CF_1	=	Conversion factor (24 h/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 2.1 for migration rate inputs and determination of these values.

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

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

Where:

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

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

The article model in CEM E6 calculates BBP 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 BBP 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 BBP-containing dust. The model uses a weighted dust concentration, shown in Equation_Apx A-18.

Equation_Apx A-18. Chronic Dust Concentration

$$Dust_{cr\_wgt} = \frac{\left(RP_{floor\_avg} \times BBPRP_{floor\_avg}\right) + \left(Dust_{floor\_avg} \times BBPDust_{floor\_avg}\right) + \left(AbArt_{floor\_avg} \times BBPAbArt_{floor\_avg}\right)}{\left(RP_{floor\_avg} + Dust_{floor\_avg} + AbArt_{floor\_avg}\right)}$$

Where:

$Dust_{cr\_wgt}$	=	Chronic weighted dust concentration (µg/mg)
RP_{floor_avg}	=	Average RP mass, floor (mg)
$BBPRP_{floor\_avg}$	=	Average BBP in RP concentration, floor (µg/mg)
$Dust_{floor\_avg}$	=	Average dust mass, floor (mg)
$BBPDust_{floor\_avg}$	=	Average BBP in dust concentration, floor (µg/mg)
$AbArt_{floor\_avg}$	=	Average abraded particles mass, floor (mg)
$BBPAbArt_{floor\_avg}$	=	Average floor dust BBP 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 BBP can volatilize from the BBP-containing article to the air and then partition to dust. Alternately, BBP 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 BBP 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 in µg/kg-day) CEM output for that product using the same inputs summarized in Table 2-5 for inhalation and Table 2-8 for dermal. EPA used professional judgment and product use descriptions to estimate events per day and per month for the calculation of the intermediate dose, as follows:

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	Events Per Month
Patching and repair products for exterior surfaces	1	2
Sealing and refinishing sprays (indoor use)	1	2
Sealing and refinishing sprays (outdoor use)	1	2

A.4 Dermal Absorption Modeling

After calculating dermal absorption dose per event for each life stage, 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}